APPENDIX D

LAKEBELT WILDLIFE STUDY

DADE COUNTY LAKE BELT PLAN

WILDLIFE STUDY - FINAL REPORT

Submitted to

DADE COUNTY

DEPARTMENT OF ENVIRONMENTAL RESOURCES MANAGEMENT

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EXECUTIVE SUMMARY

The Lake Belt Study Area (LBSA) of northwestern Dade County covers 47,921 acres (EAS Engineering, Inc., 1995). The region includes approximately 7,500 acres of sawgrass marshes with little to no invasion by the exotic pest plant *Melaleuca quinquenervia* (melaleuca). The area also includes approximately 8,100 acres of moderate coverage by melaleuca (10% to 75% melaleuca) and 17,300 acres with greater than 75% coverage by melaleuca. The remainder of the area is composed of lakes, littoral zones, agricultural lands, canals, levees, correctional facilities, electrical power facilities, and power line right-of-way (EAS Engineering, Inc., 1995). In many areas, there is a high degree of interspersion of habitat, so that areas with high melaleuca coverage are adjacent to areas with low or no melaleuca coverage. This mosaic of habitats may increase the ability of animal populations to persist in areas with high melaleuca coverages. Further, the western boundary of the region is adjacent to Water Conservation Area (WCA) 3B. Species with high vagililty, such as wading birds, seasonally move between the LBSA and WCA 3B.

The Wildlife Studies portion of the Lake Belt Ecological Studies evaluated wildlife diversity and habitat use of melaleuca impacted wetlands. It required monthly sampling, using multiple techniques, in five cover types. The cover types were defined by the percent coverage of melaleuca. Other factors, which may effect wildlife distribution and abundance, such as hydrologic regime or surrounding habitat, were not controlled variables in the contracted sampling design.

Findings to date suggest:

1. Cumulative numbers of species were highest in areas with moderate melaleuca coverage (Marsh has less than 10% melaleuca coverage while DMM and SDM more than 75% melaleuca coverage). The number of species (species richness) is not, by itself, a good measure of the environmental value of a habitat. Numerous studies indicate that disturbed areas have higher diversity than natural areas. Which species are using a habitat is most important to final evaluation of habitat quality.

2. Species composition was evaluated based upon the "wetland association" of amphibians, reptiles, birds, and mammals. Areas with low melaleuca coverages had more species that were fully dependent or seasonally dependent upon wetlands (Fig. 36, 37). Areas with moderate levels of melaleuca retained a high number of wetland associated species, but also had additional species not typically associated with natural graminoid wetlands. Areas with high melaleuca coverages had similar number of species as areas with low melaleuca coverage, however, many of these species were not typical of natural graminoid wetlands.

3. Cumulative number of individuals was highest in areas with low to moderate melaleuca coverage. This was mainly the result of the higher abundance of Crayfish, Grass shrimp and fishes in these areas during the wet season. High abundance of

these animals is important in maintaining higher-level consumers (e.g., many reptiles, wading birds).

4. Fifteen non-native species of vertebrates were trapped in the five defined cover types for wildlife sampling (Tab. 14) during the 24 months of the study. The percentage of the 24 month cumulative numbers of species and individuals that were non-native was highest in dense mature melaleuca (DMM) and in dense sapling melaleuca (SDM). Overall, cichlid fishes were the most abundant group of non-native animals trapped. An additional five species of non-native vertebrates were observed along levees within the study area.

5. In summary of the above results, the data after 24 months of sampling indicated that as succession proceeded from 50-75% melaleuca coverage (P75) to 75-100% coverage (either mature or sapling state), the number of wetland associated species decreased, the number of non-native animals increased, and overall species abundance decreased.

6. Red imported fire ant mounds (RIFA) were absent in marshes with low levels of melaleuca and rare in mature dense melaleuca stands (Fig. 35). The highest numbers were found in areas with moderate levels of melaleuca (50%-75% melaleuca, P75 cover type). This cover type does not have as a high soil moisture content as the marshes nor the nearly complete canopy shading of mature dense melaleuca stands. As standing water levels increased, the number of ground active mounds decreased. It was noted that at least some of the mounds moved into the bark of melaleuca trees.

7. Eleven listed species were observed in the LBSA (Tab. 13). *Endangered Species.* The Wood stork was the only Endangered species observed in the LBSA. It is listed at both the State and Federal levels. Both adult and juvenile Wood storks were observed foraging in the study area. *Threatened Species.* The American alligator was the only species listed as Threatened (Similarity of Appearance) at the Federal level that was observed. The alligator is listed as a Species of Special Concern at the state level (see definition below). The Least tern is listed at the State level as Threatened, but does not have any designation at the Federal level. It was observed aerial foraging along canals. *Other State Listed Species: Species of Special Concern.* Seven species listed as SSC were observed in the LBSA. These species are: American alligator (see above), Gopher tortoise, Snowy egret, Tricolor heron, Little blue heron, White ibis, and Roseate spoonbill. A single Gopher tortoise was found along a levee. Suitable habitat for this species does not exist in the LBSA. The occurrence of this individual was anomalous. The remaining five species of wading birds seasonally foraged within the LBSA. *Other Federal Listed Species: Candidates (C1 and C2) and Under Review (UR).* Three species designated C2 has been observed. These species are: Gopher tortoise (see above), Island glass lizard, and Loggerhead shrike. The latter two species were trapped or observed numerous times. Neither the Island Glass lizard or the Loggerhead shrike have any designation at the state level.

8. While rainfall during the two years of this study was high, annual mean water levels at gages in the LBSA were within normal ranges (Fig. 4). The effect of well field pumping and other water management strategies may effect the relationship between rainfall and standing water levels in an unnatural manner. Results of this study cannot be seen as unusual for the area or as an artifact of periods of high rainfall. Moreover, the large number and the range of age classes of many of the wetland dependent animals trapped indicated normal, resident breeding populations.

9. There were two principal physical gradients in the Lake Belt Study Area environment: melaleuca density and water levels. Melaleuca density was a geographic gradient, with density varying primarily from east to west. Water level was primarily a temporal gradient, varying with seasonal rainfall. The dominant characteristic of the faunal shifts along the gradient of increasing melaleuca coverage was increased numbers of upland, arboreal, and, or forest species, not the loss of wetland species. The dominant characteristic of the faunal shifts along the gradient of water level was seasonal variation in abundance of wetland species.

10. Community composition of fishes and herptiles was most strongly related to gradients of water level. Community composition of birds and mammals was most strongly related to gradients of melaleuca density.

11. Lake designs that maximize mining potential appear to have minimal wildlife habitat value. Lake designs to promote wildlife habitat value would not realize full mining potential. Therefore, two types of lakes should be considered. Lake designs that maximize mining potential should be located east of the FPL R/W. Lake designs that promote wildlife habitat should be located between the FPL R/W and the Dade-Broward Levee. The area west of the Dade-Broward Levee should have no mining activity. This area, known as the Pennsuco wetlands, currently is a functioning marsh, and should be maintained with appropriate seasonal variation in depth and duration of flooding. These suggestions are consistent with the initial configurations being considered for hydrological modeling by the South Florida Water Management District.

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SCOPE OF REPORT

This is a draft final report for the Wildlife Studies Portion of the Lake Belt Ecological Studies. All final deliverables as delineated in the contract between Metropolitan Dade County, Department of Environmental Resources Management and EVERGLADES RESEARCH GROUP, INC. are presented for the period January 1,1994 through December 31, 1995:

1. A list and map that show the approximate positions of all sampling sites for all portions of the contracted work (Tab. 1; Fig. 2).

2. A species list for all taxonomic groups listed in the award, by cover types (Tab. 3).

3. Rarefaction curves and analyses for taxonomic groups listed in the award. The curves show the plot of cumulative species vs. cumulative individuals sampled. The analyses predict the cumulative number of species expected by cover type (Figs. 11, 18, and 25).

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Appendix II. Random sites sampled each month.

Appendix III. Statistical formulas and outputs.

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Appendix V. Clarifications of species identifications or designation.

INTRODUCTION

The Lake Belt Study Area (LBSA) of northwestern Dade County covers 47,921 acres (EAS Engineering, Inc., 1995). The region includes approximately 7,500 acres of sawgrass marshes with little to no invasion by the exotic pest plant *Melaleuca quinquenervia* (melaleuca). The area also includes approximately 8,100 acres of moderate coverage by melaleuca (10% to 75% melaleuca) and 17,300 acres with greater than 75% coverage by melaleuca. The remainder of the area is composed of lakes, littoral zones, agricultural lands, canals, levees, correctional facilities, electrical power facilities, and power line right-of-way (EAS Engineering, Inc., 1995).

The region's hydrology, water storage and water quality, as well as wildlife resources, and general environmental values must be evaluated before a thorough plan for land use may be developed. Previous studies on wildlife use of melaleuca have focused on either a few species (Mazzotti et al., 1981; Sowder and Woodall, 1985) or surveyed only dense melaleuca stands (Schortemeyer et al., 1981; Repenning, 1986). The objective of the Wildlife Studies portion of the Lake Belt Ecological Studies was a thorough evaluation of wildlife species diversity and habitat use of areas described as marsh, exotic plant invaded marsh, dense melaleuca, and other natural and man-made habitats. Wildlife was broadly defined to include selected macroinvertebrates (Crayfish, Grass shrimp), as well as fishes, amphibians, reptiles, birds, and mammals.

The study required a series of regular samplings of wildlife in a variety of cover types for a two year period. This report analyzes the data collected during the two years.

COVER TYPE TERMINOLOGY

Previous descriptions of the natural wetlands of the study area, especially the area called the Pennsuco wetlands or Pennsuco Everglades located west of the Dade-Broward Levee, have described them as prairies and, or short hydroperiod wetlands (Larsen, 1992; EAS Engineering, 1995). The classic vegetation survey by Davis (1943) characterized most of the area as "saw-grass marshes (medium dense to sparse)", with the southeastern corner characterized as "saw-grass marshes (with wax myrtle thickets)". Davis mapped a "wet prairie" cover type, but it occurs to the east of the LBSA. Reconstruction of pre-drainage conditions by Everglades National Park (ENP), the Army Corps of Engineers (COE), and the South Florida Water Management District (SFWMD), all include these wetlands as part of the long hydroperiod marsh of northeastern Shark River Slough (Fig. 1; also so Fennema et al., 1994). Recent hydrological records demonstrate that the Pennsuco wetlands are still flooded for more than six months a year under "normal rainfall" (1986; Davis et al., 1994). Soils are classified as muck or peat soils, with depths up to 1 meter (EAS Engineering, 1995). The existing dominant vegetation is dense sawgrass, one to two meters tall. Finally, the data on the wildlife of the region presented below clearly indicate a wetland community typical of long-hydroperiod marshes.

Therefore, based upon both historical and existing conditions, these wetlands should be characterized as "marsh", not "prairie". We have used the term marsh, as opposed to prairie, throughout this report to make this designation clear. Continued use of the term prairie or short hydroperiod wetland for these marshes, could lead to a serious error in evaluating their current values as well as their future role in the implementation of a Lake Belt Plan, the Lower East Coast Buffer Zone, and restoration efforts for the Northeast Shark River Slough.

Five cover types were designated for sampling of Wildlife by the Lake Belt Studies Environmental Review Committee. Cover types were defined by the committee based upon percent coverage by melaleuca. The following abbreviations for the five cover types defined for wildlife sampling were used in the text, tables, and figures.

Note: Previous reports on the Wildlife Studies portion have used the cover type abbreviations listed in the original RFP. The new abbreviations are as follows, with the previous abbreviation given in parentheses:

DMM **75 - 100% mature dense melaleuca coverage (CT 1)**
DBH of trees > 3 inches; moderate stem density
SDM **75 - 100% sapling dense melaleuca coverage (CT 2)**
DBH of trees < 3 inches; very high stem density
P75 **50 - 75% melaleuca coverage (CT 3)**
P50 **10 - 50% melaleuca coverage (CT 4)**
Marsh **0 - 10% melaleuca coverage (CT 5)**

A detailed vegetation map of the area was not available when site selection for the Wildlife Studies began. Potential study sites were identified from the vegetation map in Larsen (1992) and 1992 aerial photographs. Actual site selection was determined by ground-truthing. Several site visits were made with DERM staff and vegetation experts from EAS Engineering, Inc., in an effort to assure consensus of cover type designation.

Photographs of representative sites of each cover type can be found in Appendix I of this report.

SITE SELECTION

Each site selected for repeated sampling had to be accessible on foot from an existing grade (e.g. levee, or right of way), and cover a minimum of one acre (based upon the scale of vegetation mapping).

Based upon the original specifications of the contracted work, three locations (replicates) of each of the five cover types were selected (15 sites total). Scouting of the area during early December 1993 indicated a general hydrological gradient along a north-south axis in the study area. Further, most of the P50 and P75 cover types mapped were located north of the Pennsuco Canal. Since we were limited to three replicates per cover type and the contract required that data analyses include one-way Analysis of Variance to test for difference between melaleuca cover types, sites were chosen to minimize hydrological variation. During the site selection process in December 1993 and January 1994, ERG staff escorted vegetation experts from EAS Engineering and DERM staff to potential sites. A cover type designation was agreed upon in field for 13 of the 15 selected sites. At this point, EAS and DERM staff decided that field visits to remaining sites were not necessary. When the location of the sites was presented to the full Environmental Review Committee in February 1994, concern was expressed that the sampling did not cover a broad enough area. Therefore, the sampling procedure was modified. The existing three replicates per cover type continued to be sampled on a monthly basis by drift fencing only. An additional seven sites for each cover type were to be selected, to bring the total to ten replicates for each cover type. Three of these ten replicates would be randomly selected each month for sampling by all methods other than drift fencing. Some of the additional sites were identified solely from recent aerial photographs and the vegetation map in Larsen (1992). Complete ground truthing of all sites was completed over a period of months, as the sites were randomly selected for sampling. If, upon ground truthing, the cover type designation differed from that initially identified from aerials, the cover type designation from ground truthing was given preference. Depending on the circumstances, the site was included using the ground-truthed designation, or a new location was selected after ground-truthing. Any discrepancies between earlier maps and the current map of approximate site locations are primarily the result of further ground-truthing.

As stated earlier, the intensive site preparation required for some sampling techniques (e.g. drift fencing) required that three sites for each cover type were repeatedly sampled each month (indicated by an asterisk in Tab.1 and Fig. 2). Repeated sampling of the same sites over time would allow for statistical tests not permitted by sampling of random sites over time. The locations of the repeatedly sampled sites were selected to minimize hydrological variation for statistical rigor in a one-way Analysis of Variance. Other sampling techniques required little site preparation, and therefore, allowed sampling to occur in a random subset of three of the ten sites in each cover type on either a monthly (dip netting, minnow trapping, faunal transects, bird transect) or quarterly basis (red-imported fire ant surveys and mammal surveys). This procedure permitted a wider range of sites to be sampled. However, since the replicates within cover types were not from identical locations each sampling period, this data could not be analyzed by ANOVA as cumulative samples from the same place over time (see Statistical Procedures below). Nevertheless, these data could still be analyzed as pooled samples for chi square tests, Index of Dispersion assessment, cluster and principal component analyses.

As a general rule, hydropattern is a strong determinant of wetland species diversity and abundance (Mitsch and Gosselink, 1986; Campbell and Christman, 1982; Dalrymple, 1988). Drift fencing required the same 15 sites to be visited at least 5 times per month for each of the 24 months. This regular, repeated sampling of the same site over time allowed an understanding of the range of field hydrological conditions experienced by a site through time. Most other methods required a random selection of sites each month. Random sampling of sites only gave a point estimate of field hydrological conditions on the day of sampling. Since hydrological conditions of a site are determined by a combination of rainfall, surface elevation, microtopographic variation, and water management practices, actual standing water levels cannot be predicted from one variable alone (e.g. rainfall or topography). While empirical measurements of standing water levels at each site during sampling were made, a more thorough history of water levels at drift fence sampling sites aided our biological interpretations.

SAMPLING METHODS

The Everglades region presents some unique sampling problems. The shallow freshwater habitats can be difficult to sample for aquatic organisms (Kushlan, 1974), and likewise the seasonal flooding of habitat makes sampling for semi-aquatic and terrestrial animals difficult (Dalrymple, 1988). There may be too little water to get a sample of fish at one time, and yet the standing water may flood traps and kill semi-aquatic and terrestrial animals at other times. For this reason some cover types can only be sampled effectively by some methods during certain seasons of the year, and multiple sampling methods may be required to obtain representative samples of all the fauna (Kushlan, 1974).

While drift fencing was performed at the same sites each month, the other methods were performed at a random subset of three sites. Random selection of the three sites in each cover type was done prior to data collection, using a random number generator. Dip netting, minnow trapping, faunal transects, bird transects, and RIFA surveys were performed as feasible at the these sites. Additional sites were not chosen if one or more of the three randomly selected sites did not have the appropriate hydrological conditions for sampling by a particular method. Sampling the next month was done at a different subset of randomly selected sites. A similar method for site selection was followed for small mammal live trapping and scent and bait stations with the following exception. Since only one replicate per cover type was performed, if the first randomly selected site was not feasible for sampling, then two other sites were randomly selected. Sampling was deemed "not feasible" only if each of these sites were too wet for sampling. A listing of which sites were sampled each month is available in Appendix II. Where sampling procedures could not be performed due to water conditions (e.g. too wet for small mammal live trapping, or too dry for minnow traps), the summary indicates no sampling with the use of the symbol x. The dash symbol (-) indicates that sampling was performed, however no animals were collected in the sample. The end result is the same, i.e. zero data, but the distinction is made to make it thoroughly clear when a sampling method was not feasible. In all statistical tests (see next section), the sums of x's are treated as 0's (zeros) for testing purposes.

For each sampling technique, the methodology, frequency of survey, number of replicates, the types of animals sampled, and sampling limitations are described in detail below and summarized in Tab. 2.

Dip net sampling

Monthly sampling of three randomly selected sites in each cover type (15 sites total). Both dip netting and minnow trapping provide a relative abundance of fishes, Odonate larva, snails, grass shrimp, and crayfish. Occasionally, aquatic amphibians and reptiles were also captured.

Dip netting was performed using a fixed area/fixed time method. Five sweeps of the dip net were taken at approximately 5 minute intervals (the time required to sort the contents of the net into a sampling jar). Dip netting requires at least one square meter of one inch of water.

Minnow trap sampling

Monthly sampling of three randomly selected sites in each cover types (15 sites total). here were 15 traps per sites, checked 24 hours after deployment. When water levels were high enough, half of the traps were allowed to float at the surface, while the other half were weighted to rest at the bottom of the water column. Minnow trapping required at least 12 inches of standing water.

Drift fence arrays

Monthly sampling of three permanent sites in each cover type (15 sites total). Drift fence trapping in this study was used as a sampling method for all aquatic, semi-aquatic and terrestrial macroinvertebrates and vertebrate animals.

A drift fence array is simply a vertical barrier along which traps are placed. The design and placement of the traps depends upon the target species. Drift fence trapping has been a traditional method for sampling amphibians and reptiles in mesic and xeric habitats (c.f. Heyer et al., 1994). The use of a vertical barrier with associated traps has also been used to sample fishes and macroinvertebrates (McIvor and Odum, 1986, 1988; also see USFWS Commercial Fisheries Circular 48). In studies of the amphibians and reptiles of the Long Pine Key region of Everglades National Park, the Pa-hay-okee marshes of Everglades National Park, and the Big Cypress National Preserve, drift fences designed to trap amphibians and reptiles also regularly trapped high numbers of Crayfish, Grass Shrimp and fishes (Dalrymple, 1988; G.H. Dalrymple and F.S. Bernardino, unpublished data; Dalrymple, G.H., 1995).

Drift fence arrays were constructed using shade cloth. The array had four 15 m long by 1 m high arms, arranged as a cross [+]. Traps were constructed of 1/8" gauge galvanized hardware cloth, with two funnels at one end of the trap. One trap was placed at the end of each arm of the array, so that one funnel rested on each side of the fence (as done by Dalrymple, 1988). Pit fall traps were not feasible since the soil was saturated. Under these conditions, traps will not stay in the ground.

Drift fence arrays were checked four days per month, generally, every other day over a eight day period. Arrays were maintained so that the fencing remained upright and no gaps developed between the fencing material and the ground. Funnel traps were repaired or replaced as needed. When the traps were not being checked, they were removed from the end of the fence and the funnels were blocked to prevent an animal from entering the trap.

The number of amphibians, reptiles, fishes, small mammals, and macroinvertebrates were listed and analyzed from drift fence arrays. The numbers of each species were evaluated as animals per array day (number of days array traps were open) for comparison to other studies using this technique.

Standing water depth during drift fence trapping does not preclude trapping. The time period between trap check days was modified when traps were underwater to minimize mortality of amphibians and reptiles. The number of check days remained the same. Trap rates were calculated using the number of days the arrays were operated, not the number of times the traps were checked.

Faunal transects

Monthly sampling of three randomly selected sites in each cover type (15 sites total). Transects, 100 meters long and 10 meters wide, were searched for mammal tracks and scats, amphibians and reptiles, as water levels permitted. Data are presented as presence or absence only. One mammal could imprint a series of tracks or leave multiple scats. Amphibians were identified by sight or by vocalization. It was not possible to accurately determine the number of individuals in a breeding chorus of frogs.

Faunal transects required that standing water levels were less than six inches, since mammalian sign is not evident under these conditions.

Bird strip transects

Monthly sampling of three randomly selected sites in each cover type (15 sites total). Bird strip transects were a fixed length of 100 meters. The width of each transect was determined by the furthest distance to a bird observed during the transect. If the bird was flying overhead or could not be positively identified, it was not recorded. All data were collected between sunrise and 11 a.m. The order in which cover type sites were sampled was randomly chosen each month.

Strip transects for birds in this study were designed to focus on the birds that have limited daily cruising radii and, therefore, were most likely to identify habitat preferences based on vegetative cover, rather than hydrology. Perching birds (blackbirds, shrikes, warblers, cardinals), other land birds (doves, kingfishers, woodpeckers), some smaller wading birds (snipe, and rails), and some birds of prey are usually studied to evaluate between habitat differences in vegetative cover (Stauffer and Best, 1980). Such surveys also allow assessment of habitat use by migratory and/or transient birds versus resident breeders (Keller et al, 1993).

Information on wading bird and water bird use of the study area was most commonly collected in road/levee surveys, see below). Wading birds have daily cruising radii from roosting to foraging sites of up to 35 km (Frederick and Collopy, 1988). The wading birds move about looking for any source of standing water that is currently at the proper depth to allow them to forage. For that reason, they will fly in and out of most cover types, including forested wetland swamps, to use the standing water. Likewise the duck-like birds, cormorants, anhinga, and some birds of prey are not good indicators of how subtle shifts in tree coverage affect habitat use by birds. The latter groups of birds are best studied on a much broader habitat scale, and one that focuses on hydrology of wetlands, lakes, and littoral zones, and gives flock counts, and or relative abundance data.

Road surveys

Monthly sampling of the FPL right-of-way, Well field Canal levee, and Krome Avenue. Monthly estimates of habitat use, and relative abundance of small mammals, amphibians and reptiles, and birds were made from road cruising surveys. Relative abundance of turtles and alligators using the Well field Canal were also collected during these surveys. Preliminary surveys indicated a difference in the distribution of wading birds along the Well field Canal and the FPL right-of-way. Therefore, each of these two roadways were subdivided for data recording. The levee associated with the Well field Canal is divided into two sections: a north-south section and an east-west section. The north-south section is referred to as the improved portion of the Dade-Broward Levee (D-B Levee in tables). The Well field canal runs along the east side of the Dade-Broward Levee. Along the west side of the levee are three shallow mitigation areas. Each mitigation area is approximately 0.25 miles long and retains water year round. The FPL right-of-way(R/W) was divided into a "north" and "south" section, with the boundary being the Pennsuco Canal.

Surveys of Krome Avenue (western border of study area) focus on animals physically on the road, usually dead. These surveys are limited, since Krome Avenue is a high-speed traffic road. Birds can not be surveyed along Krome Avenue.

Red imported fire ants (RIFA)

Quarterly sampling of three randomly selected sites in each cover type (15 sites total). Estimates of red imported fire ant (RIFA) density by cover type used three 1/10 ha circular sample plots done in triplicate in each cover type on a quarterly basis(Allen, 1993 and manuscripts). The diameter and height of each mound was categorized as small, medium or large. Each mound was probed with a stick to determine whether it was active or inactive. Active mounds always had great numbers of ants emerge within seconds of testing. Since the meaning of inactive mounds is unclear at this time, the data is reported but not analyzed further (Allen, 1993, and manuscripts).

Live trapping for small mammals

Quarterly sampling of one randomly selected site per cover type (5 sites total). Small mammal live trapping was done quarterly in the 5 cover types. One randomly selected site in each cover type was sampled using a set of 15 Sherman live traps for rat-sized mammals, paired with 15 Sherman live traps for mouse sized mammals. The traps were laid out in pairs along a transect through each sampling site. The trap pairs were placed 10 m apart, and baited with oats. Traps were checked for 3 consecutive mornings. The numbers of each species of small mammal trapped in live trap sampling arrays were listed and analyzed. Live trapping required no standing water.

Scent and bait stations for medium to large mammals

Quarterly sampling of one randomly selected sites in each cover type (one of each station per cover type; 5 sites total). Stations consisted of an attractant elevated on a post 0.5 m above the ground. The post was surrounded by a one meter square area that was cleared of vegetation, covered with two to three inches of fine sand, with the surface troweled smooth. The sand must be fine grained so that tracks of animals weighing one to twenty pounds will clearly imprint. The attractant in the center of the scent stations was a strap of rug covered with animal feces or urine, and at the bait station, an aluminum pan filled with an oily, tuna flavored pet food. On three consecutive mornings, the sand around the stations was examined for tracks, cleaned, and smoothed out. Scent stations and bait stations required no standing water.

Species lists (presence/absence during a sampling period) were generated. The same individual could visit a station over consecutive nights (i.e., the same raccoon could visit the station each night). Further, any animal visiting a station was likely to leave multiple tracks.

Seasonal variations in hydrology, sampling technique applicability to hydrology, and quarterly results

Some variation in species occurrence within and between cover types is a function of water levels. Each time a site was selected for sampling, standing water depth was estimated using a meter stick. These estimates of surface water depths were intended as a preliminary aid to understanding biological issues, not as a final statement regarding hydrological issues within the study area.

During the first quarter all cover types were showing progressive drying, while during the second quarter they were showing very unpredictable short term flooding, due to episodic rainfall. During the third quarter, Marsh cover types had continuous standing water levels varying in depth between 15 and 30 cm. Each of the other four

Cover types experienced recurring episodes of intense, localized rainfall resulting in short term flooding. A site could have no standing water one day, the next day have at least 5 cm of standing water, and two days later have no standing water. Cover types P75, SDM and DMM experienced more fluctuations in standing water levels during the third quarter than did P50. Such variations are normal and reflect the seasonal shifts in habitat use by wildlife and fishes.

During the fourth quarter, DMM and SDM both had periods of no standing water while P75 and P50 had continuous minimum standing water levels of 8 cm. Maximum standing water levels at all sites in DMM, SDM, P75 and P50 were approximately 50 cm, following Tropical Storm Gordon (November 14 thru November 16, 1994). Marsh had continuous minimum standing water levels of 35 cm and maximum levels of 70 cm following Tropical Storm Gordon.

During the fifth quarter, monthly rainfall still exceeded averages expected for each month. Still, all areas experienced decreasing standing water levels. All sites in Marsh (0% to 10% melaleuca) still had some standing water toward the end of March. At least some of the sites in the other cover types had completely dried out at some point during the quarter. The heavy rains experienced in mid-March resulted in some sites which had previously dried re-flooding.

During the sixth quarter, sites were generally dry during April. Heavy, sporadic rainfall began in early May. All sites had fluctuating water levels throughout May and June.

During the seventh quarter, most sites had continuous standing water. Only a few sites had a brief interval (3 to 7 days) without standing water in mid to late September.

During the eighth quarter, most sites had continuous standing water. Southern Florida experienced unusually heavy rainfall October 16 through October 19. It is estimated that the Lake Belt Study Area received 12 cm to 18 cm of rainfall during these three days. By mid-December, some sites in the northern portion of the study area were either dry or had scattered puddles of water while some sites in the southern portion of the study area still had 15 cm to 30 cm of standing water.

RAINFALL AND STANDING WATER LEVELS

The South Florida Water Management District (SFWMD) has described the 1994-1995 period of rainfall and hydropattern as a "25-year" high water event throughout Dade County (add lit cite). But in individual basins of water management, such as Water Conservation Area 3B, the Bird Drive Basin, or the Pennsuco-Lake Belt Study Area, the relationship of standing water to rainfall may be dramatically effected by regional patterns of water management and use. Pumpage for drinking water well fields, and, or water releases from basin to basin may affect the actual standing water levels in an unnatural manner.

As a preliminary assessment of the relationship between the regional high rainfall event and the actual water levels in the LBSA, two data sets were gathered through the Water Resources Section of DERM. The first data set was monthly rainfall at Miami International Airport for the two year period of sampling. MIA recording station was chosen because of its proximity to the LBSA. The second data set was the eleven year period (1985 to 1995) of water levels measured at two permanent USGS wells in the LBSA. Two gages were selected. One gage was located west of the Dade-Broward Levee (G-975) and the other east of the Dade-Broward Levee (G-972; see Fig. 2).

We recognize that a full and thorough assessment of water management issues is being performed by the SFWMD. However, the results of this study are not available at this time. Our analyses were simply intended to aide in biological interpretation of the results. Ultimately, the biological assessment would be greatly enhanced by the addition of: 1) the final vegetation map and analyses; and 2) a final agreement on ground surface elevation at USGS wells within the LBSA to permit assessment of actual standing water levels.

STATISTICAL METHODS

Perspective on testing

The current study was designed to address questions of wildlife use of habitat that varied in the degree of melaleuca cover. It could not address more fine-scale resolution of variation within a cover type. It is well known that in the ecological sciences, field studies do not lend themselves to simple significance testing - there are too many uncontrollable variables involved. In ecological field studies, we cannot control for microtopographic effects, rainfall, water management, water depth, flooding duration, soil variations, and autocorrelations caused by spatial patterns. The goals of field data analyses should be to identify gross patterns of habitat use, and to identify the specific ecological requirements of the species found in the area. Our goal in this study was to identify groups of species that indicate the quality of habitat types along the single gradient of the degree of melaleuca coverage, without presuming to explain the degree of variability associated with all the other uncontrollable variables.

Data sets and analyses

Cumulative two year data sets for macroinvertebrates, fishes, and amphibians and reptiles (herptiles) collected by site specific repeated samplings over time, from drift fence data sets, were analyzed by ANOVA, with 3 replicates per cover type. These data sets were analyzed by parametric ANOVAs of the raw data, and of the log transformations of the raw data (to adjust for deviations from normal distribution). The data were also ranked, and analyzed by non-parametric Kruskal-Wallis ANOVA as a check on distribution effects. In all cases, neither log transformation or ranking altered the results of hypothesis testing of the raw data (only the exact probability values differed). If had been differences in results from the use of multiple tests, it would have been reported. Therefore, we reported only the resultant test statistics, and p values for the raw data sets.

The Environmental Review Committee required that some sampling procedures (bird transects, mammal traps, faunal transects, Red Imported Fire Ants (RIFA), minnow traps, and dip nets) be based on random site selections per sampling event. Cumulative data generated by this sampling protocol could not be analyzed by ANOVA, because site-specific repeated measures were not available. No parametric or non-parametric test of means or medians is available for these data. Such statistical tests require independent replicates (repeated measures) of the same sites, at the same time.

The above limitations are not critical to statistical analyses in ecological sciences. Simple statistical tests for average differences between cover types in numbers of individuals, or numbers of species reveal a limited amount about the ecological nature of cover type differences. They are useful for recognizing gross differences in species richness, or diversity, but say little about the species composition of the cover types. Therefore, **multivariate techniques**, which permit evaluation of the individual species' contributions to cover type differences (and vice versa) were used.

Data sets collected at standard sites, such as drift fence data for fishes, herptiles, or macroinvertebrates, were analyzed using the multivariate techniques of cluster analysis, factor analysis and, or multidmensional scaling. These analyses have the same three replicates for each cover type sampled each month, and allow us to see more of the variation among sites within the same cover type. The plots of these analyses will have three replicates for the five cover types, entered separately and plotted separately. These data sets had enough replicates to permit factor analyses as well as cluster analyses and multidimensional scaling. For example, the herptile drift fence data has a matrix of 36 rows (species) by 15 columns (locations), i.e. a 36 x 15 matrix.

Cluster analyses were done using the unweighted pair-group average (UPGMA) amalgamation method of joining groups. The joining was done on a distance matrix generated as the subtraction of each Pearson's product moment correlation coefficient from unity (1.0 , i.e. 1-r), to generate the distances. If for example two cover type sites or species had a correlation coefficient of 0.91, then their distance is 1.0 - 0.91, or 0.09 (i.e. they cluster close together). The **factor analysis** method used was the unrotated matrix of **principal components** based on the same matrices of correlation coefficients. These methods are standard procedures, and incorporate the least manipulation of the original data (unlike, e.g. varimax rotations, etc.). Additionally, **Multidimensional Scaling** was used to corroborate the results of the factor analyses.

Multivariate matrices were derived from both the raw data and from transformations of the raw data as percentage occurrence per species (to remove absolute sample size effects). Transformations neither changed, nor enhanced results (two example of results by raw vs. transformations is given in Figs. 3 and 22). Therefore, to include the effects of differences in absolute sample sizes, multivariate matrices derived from the raw data sets were given preference over matrices derived from transformed data.

Additionally, in factor analyses, a variety of methods and rotations of data were applied. Again, they neither changed, nor enhanced results from analyses of raw data sets (such methods include principal component analysis, Communality analysis, Principal axis methods, and Maximum likelihood analysis; as well as Varimax and Equimax rotations). Therefore, we reported only the results of multivariate analyses for the raw data sets.

The one exception to the above preference for raw data, was with the application of multivariate techniques to a qualitative (presence/absence) data set for 133 taxa. This qualitative data set included all species of macroinvertebrates, fishes, herptiles, birds, and mammals that occurred in at least one of the five defined cover types (133 taxa total). It was impossible to obtain a clear pattern from the raw data for all these groups simultaneously, because of the wide variation in capture rates (e.g. over a thousand for some invertebrates, several hundred for some fishes, but ten or less for many herptiles, birds, or mammals). n such cases, standardization, either as normal deviates or percent composition, did not remove this variation. Scoring species as present (= 1) or absent (= 0) simplified the matrix to generate an overall pattern of species richness that was easily interpreted.

Data sets that were collected using randomly located sites do not have the same physical replicates between samplings, and in these cases the data for each cover type was lumped together to represent the overall pattern for the cover type. For example the bird transect data had a matrix of 46 rows (species) by 5 columns (cover types), i.e. a 46 x 5 matrix. With only five columns, these matrices were analyzable by cluster analysis, but not by factor analysis.

Hierarchy of analyses and transformations of data sets

Given the fact that some methods collected larger data sets than others (i.e. drift fences compared to dip nets and minnow traps), the statistical usefulness of a sampling method was defined as the total amount of information that the method contributed to species richness (measured as number of species per cover type), and relative abundance (measured as total raw sample sizes). In all cases the results (see below) identified the drift fence as yielding the most information on species richness and relative abundance.

For the above reasons, the results of the statistical analyses (including parametric and multivariate methods) applied to the drift fence data are presented in detail (with tables and figures). The tests done to identify the most robust data set are presented as a preliminary to detailed results in each taxonomic group assessed.

In the same context, both bivariate, parametric, and multivariate analyses of presence/absence data and data sets transformed as percent composition, added no information, i.e. clarified no patterns identified using the raw data. While all contractually required analyses of transformed data (both presence/ absence, and percent composition) were performed, each separate analysis was not included in this report. Since the analyses generated similar results, inclusion of each would simply add to the bulk of the report, without enhancing the interpretation (examples are included in Fig. 3). The results of these transformation analyses were presented to the Technical Committee's staff and are available as print-outs, and matrices for analyses as required.

In addition, log transformations of raw data sets were also analyzed for all ANOVAs that were performed, but in no case did the interpretation of statistical testing change by such transformation. Therefore, as done above for multivariate analyses, only the result of raw data testing are presented.

<u>*Tests for patterns of Dispersion and Goodness of Fit Tests*</u>

Species may show three fundamental patterns of dispersion, or distribution, among habitat or cover types: uniform, random or clumped (also called contagious or aggregated). Both the **dispersion index** and **contingency table (observed vs. expected results)** method of evaluating patterns of dispersion were used in the present study.

The Index of Dispersion (**I**) was calculated as the variance divided by the mean, of a sample of locations, where a species was recorded (Krebs, 1988; I = variance/mean). The test statistic for this index was chi square (X^2), where df (degrees of freedom) = number of locations minus 1. Interpretations were based upon a two way test, in which the null hypothesis that the distribution was random was accepted if:

$$X^2_{0.975} < \text{Observed } X^2 > X^2_{0.025}.$$

Significant differences less than 0.025 were interpreted as **clumped,** and greater than 0.975 were **uniform.**

An alternative "goodness of fit" approach to the testing of distributions was a **two by *n* table** (where n is the number of cover types, and the two alternatives were: observed numbers vs. expected numbers). As in the case of the dispersion index, the test statistics was chi square, X^2. The results of both methods are presented below.

Rainfall and hydrological analyses used in final report

Hydrological data were obtained through Dade County's Water Resources Section of DERM. Pearson product moment correlation coefficients (r) were calculated for each taxa group with water levels measured at USGS gages G972 and G975. In graphical analyses, the height of the water column and the number of individuals or species were plotted for each month. The estimated ground surface elevation is delineated as a straight line in the figures (Figs. 4-6).

Additionally, rainfall data from Miami International Airport was used for correlation analyses of numbers of individuals and species of taxa groups on a monthly basis.

HABITAT QUALITY AND SPECIES COMPOSITION

Disturbance of natural communities typically results in an increase in species diversity as "weed" species, non-native, migratory and/or species uncommon to the natural community increase in numbers (Odum, 1983). The number of species (species richness) and the number of individuals (species abundance) are not, by themselves, a good measure of the environmental value of a habitat (Van Horne, 1983). Which species are using a habitat and the manner in which they use the habitat (foraging, breeding) are more important to final evaluation of habitat quality (Stauffer and Best, 1980; Keller et al, 1993). A fair analysis of habitat quality would evaluate the types of species (e.g. wetland versus upland animals, native versus non-native), as well as their abundances.

Habitat requirements for all life history stages of each species were determined based on the literature and personal experience. Each species was then assigned to one of three categories based upon these life history traits. For the purpose of the analysis, species whose respiration, feeding mechanisms, reproduction or larval development require 9 to 12 months of standing water each year were termed **"wetland dependent"**. Species whose respiration, feeding mechanisms, reproduction or larval development require 1 to 9 months of standing water each year were termed **"seasonal wetland"**. Species whose respiration, feeding mechanism, reproduction or larval development are independent of standing water were termed **"wetland independent"**. Animals described as "wetland dependent" or "seasonal wetland" use upland habitats, but a population could not persist without suitable wetland habitat. Conversely, animals described as "wetland independent" use wetland habitats, but their life history traits allow them to survive and successfully breed outside of wetlands.

Species assigned to the same category may have different preferences with regard to timing, depth and duration of flooding. Fredrickson and Laubhan state (p. 645): **"No single wetland or wetland type will provide all the resources needed by a single vertebrate during all of its life-history stages or for all vertebrates adapted to wetlands. Thus, wetland complexes are essential for successful management"**.

Some species designations were difficult due to insufficient information and therefore, future modifications are possible. The current assigned wetland association of each species of amphibian, reptile, bird and mammal is listed in Appendix IV. This categorization was restricted to amphibians, reptiles, birds, and mammals. **Fishes were excluded because they are all, obviously wetland dependent, and were trapped in very high numbers. Therefore, they would artificially bias the results toward the wetland dependent categorization.**

RESULTS AND DISCUSSION OF RAINFALL AND STANDING WATER LEVELS

1985 - 1995 Standing water levels in the LBSA

ANOVA of water levels at G972 and G975 for the eleven year period showed significant differences in hydropattern among groups of years (G972: $F = 10.586$, $df = 10, 114$, $p < 0.0001$; G975: $F = 9.891$, $df = 10, 115$, $p < 0.0001$). This eleven year period included "low" rainfall years (1989-1991), "normal" rainfall (1985-1988), and "high" rainfall years (1994-1995). Tukey's Honest Significant Difference Tests were done to determine which years were significantly lower than 1994 and 1995 at both wells. At G972, the average monthly water level in 1994 was only significantly higher than the three drought years of 1989 -1991. In 1995 at G972, was higher than the three drought years, plus 1985 (Tukey's Honest Significant Difference Tests; Fig. 4). At G975, the average monthly water level in 1994 was only significantly higher than for the two drought years of 1989 -1990, and 1985. In 1995 at G975 was only significantly higher than the three drought years, and 1985 (Tukey's Honest Significant Difference Tests; Fig. 4). G 972 and G 975 water levels during 1994 and 1995 were not significantly higher than the three "normal" water years of 1986 - 1988.

High rainfall cannot be used to argue that the results of this study were biased toward high standing water levels. **The actual average monthly standing water levels measured at USGS gages in the LBSA were not significantly higher than during periods of normal rainfall.** Water management strategies and well field pumping are the most likely explanations. Moreover, in 1994, it was not as wet as in 1995 (Fig. 5). Yet more species and individuals were trapped in 1994 (147 species and 12,904 individuals) than in 1995 (123 species and 10,621 individuals) in the five defined cover types.

Correlations of rainfall and standing water level with trap rates

Major peaks in capture of aquatic macroinvertebrates, fishes, and herptiles were generally associated with changing water levels (either rising or falling). As a general rule, animals tended to move more when conditions were changing. Further, when standing water existed over large areas, aquatic and semi-aquatic animals were more dispersed, and capture rates were generally lower (Figs. 6,7). USGS well G972 was used as an example of the relationships in the accompanying figures. The L.S.D elevation (4.87 NGVD) was used as a conservative estimate of ground surface elevation for this well. Actual ground surface is likely to be even lower.

Correlation analyses were restricted to the faunal groups for which data were collected at standard locations by drift fence, namely macroinvertebrates, fishes, and herptiles. Monthly rainfall (MIA data), and the monthly average water levels at USGS G972 were used to calculate correlation coefficients with species and individuals. Statistical outputs for the following analyses can be found in Appendix III.

For macroinvertebrates, four replicates showed positive correlations between rainfall and number of species of macroinvertebrates, and seven replicates showed correlations between rainfall and number of individuals. For fishes, there were no significant correlations between rainfall and numbers of species of fishes and only two replicates had significant correlations between rainfall and the number of individuals of fishes. There were no correlations between rainfall and numbers of species or individuals for herptiles.

When correlation coefficients were calculated for water level at USGS G972 and the number of species, there were significant positive correlations for macroinvertebrates at eleven of the fifteen replicates (73%); for fishes at ten sites (66%); and for herptiles at only one of fifteen replicates (7%; a P75 site).

Finally, drift fence catch rates of amphibians and reptiles from this study in the LBSA were compared to average trap rates from a three year study (1984-1986) of wetlands in Everglades National Park (Dalrymple, 1988). The ENP study used the same design of drift fences, and occurred during a period of "normal" rainfall and hydropattern. Trap rates in the LBSA ranged from 0.34 to 0.69 herptiles per day, while trap rates in ENP were 1.04 herptiles per day. These trap rates indicated that if hydrological conditions were affecting yields, the result was to lower yields, not increase yields.

RESULTS AND DISCUSSION OF EACH FAUNAL GROUP

Common names of species were used in text and figures. The latin name of each species can be found in Appendix IV. Any clarifications of species taxonomy or identifications from quarterly reports were listed in Appendix V.

The overall information on species presence or absence from cover types (CT) is summarized in Table 3 and below. In this section, each major faunal group was discussed (macroinvertebrates, fishes, herptiles, birds, and mammals). Then, overall species composition and abundance across all faunal groups was compared between cover types. The presence of Endangered, Threatened, State of Florida Species of Special Concern, and USFWS Candidate species was noted by cover type. The habitats they were observed in was also noted. Species composition and abundance was evaluated by native versus non-native species and by habitat association (wetland versus upland species).

Relative value of sampling procedures

Some sampling methods collected less data than others did. The best example of this came from comparison of fishes trapped by dip netting, minnow trapping, and drift fencing. Drift fencing collected more individuals than either dip netting or minnow trapping ($F = 51.248$, $df = 2,12$, $p < 0.0001$ (Fig. 8). Even when the drift fence data was divided by four (because the drift fences were checked four times per month vs. one for the other methods), the minnow trap data were still significantly lower than the drift fence and dip methods. Similar results were obtained when capture rates of other faunal groups were compared by method. Statistical analyses improved in robustness and clarity, when both species lists, and relative abundance data (number of individuals per sample) increase. While the discussions below considered all data collected, regardless of method, in-depth quantitative analyses were restricted to the single, most robust data set.

Macro-invertebrates

Macro-invertebrates were identified or trapped in the five defined cover types by four standard methods (dip netting, minnow trapping, drift fencing, and faunal transects; Tab. 4, 5, 6-7, and 8, respectively). The first three methods trapped semi-aquatic and aquatic species (e.g. Crayfish, Grass shrimp). Butterflies and adult dragonflies and damselflies were identified during faunal transects. During the two year study period, 31 species and 10,461 individuals were trapped or identified in the five defined cover types. The cumulative number of species found in each cover type ranged from 19 (DMM) to 27 (P75). The cumulative number of individuals in each cover type ranged from 895 (DMM) to 3,718 (P50).

The most abundant invertebrates trapped were the Crayfish (5,963 individuals trapped) and the Grass shrimp (2,924 individuals trapped). **Crayfish were most abundant in P50 (2,722 individuals) and least abundant in Marsh (212 individuals). Grass shrimp were most abundant in Marsh (1,830 individuals) and least abundant in P75 (46 individuals).** These animals are preyed upon by a wide range of fishes, herptiles, wading birds, and some mammals.

Quantitative analyses presented in this report were based on the two year cumulative results from drift fencing, since this data set permitted the most robust statistical analyses (including ANOVA with triplicates per cover type). Eleven species were included in these analyses (Tab. 6).

There were no significant differences in the number of individuals ($F = 1.704$, $df = 4, 10$, $p = 0.225$), number of species ($F = 0.595$, $df = 4, 10$, $p = 0.68$), or diversity indexes ($F = 0.89$, $df = 4,10$, $p =0.1$) of macroinvertebrates between cover types (Fig. 9).

In tests of dispersion using the Index of Dispersion, all macroinvertebrates showed random distributions among cover types (statistical outputs included in Appendix III). **This indicates that cover type, defined by melaleuca cover, was not as important in the dispersion of the species as were other variables, including standing water.**

Cluster analyses revealed two main groupings of macroinvertebrates by cover types: Grass shrimp, Apple snails, Lubber grasshoppers, dragonfly larvae, and Papershell snails were predominantly found in Marshes and some of the intermediate cover type sites (P50, P75; Fig. 10). Crayfish, Dytiscid beetles, Gyrinid beetles, Ram's horn snails, and Giant water bugs, Lethocerus, were predominant in DMM, SDM and other intermediate sites.

Fishes

Fishes were trapped in the five defined cover types by three standard methods (dip netting, minnow trapping, and drift fencing; Tabs. 3, 4, and 5-6, respectively). During the two year study period, 27 species and 10,708 individuals were trapped or identified in the five defined cover types. he cumulative number of species found in the five cover types ranged from 18 (SDM) to 22 (Marsh). The cumulative number of individuals in each cover type ranged from 1,142 (DMM) to 3,250 (P50). An additional three species of fishes were observed in the study area, at sites other than the defined cover types (e.g. canals, pools along FPL R/W). These species were: Bowfin, Striped mullet, Peacock bass. It is unlikely that any of these species would survive in the seasonal wetland habitats of the five defined cover types.

The Mosquitofish was the most abundant species trapped (5,384), followed by Marsh killifish (1,092), Jewelfish (1,083) and Black acara (686).

Eight species of non-native fishes were trapped or observed in the LBSA. These species were the Jewelfish (1,083 individuals), Black acara (686 individuals), Pike killifish (111 individuals), Nicaraguan cichlid (62 individuals), Spotted tilapia (27 individuals), Oscar (23 individuals), Walking catfish (13 individuals), and Peacock bass (1 individual). We list the Peacock bass an a non-native species, yet this species is recognized by the Florida Game and Fresh Water Fish Commission as a game species and is regulated. Juveniles of five species were trapped (Jewelfish, Black acara, Oscar, Nicaraguan cichlid, Spotted tilapia). The Pike killifish, Nicaraguan cichlid, and Jewelfish are predaceous on small forage size fishes. The impact of these small to moderate size predators may have an impact on the natural recruitment of many forage fish species in the area. However, it is likely that they are preyed upon by higher level consumers.

Statistical analyses of fishes by each of the individual methods (dip, minnow, drift fencing) were done. However, not all of these methods yielded data that was as easily analyzed. Dip netting captured 2,020 individuals of 16 species of fishes (Tab. 4), minnow trapping captured 221 individuals of 11 species of fishes (Tab. 5), and drift fencing captured 8,428 individuals of 27 species of fishes (Tab. 6-7). Analyses improved in robustness and clarity, when both species lists, and relative abundance data (number of individuals per sample) increased. The raw data for fishes from minnow traps and dip nets does not yield as much information on richness and abundance as does the drift fence method. In comparison of the three methods for fishes, drift fencing collected more individuals than both dip and minnow trapping ($F = 51.248$, df = 2,12, $p < 0.0001$ (Fig. 8). Even when the drift fence data was divided by four (because the drift fences were checked four times per month vs. one for the other methods), the minnow trap data was still significantly lower than the drift fence and dip methods. Therefore, drift fencing provided the most robust data set for the in-depth quantitative analyses presented below.

Rarefaction curves for fishes indicated that, after 24 months, sampling was approaching maximum species richness in some cover types (curves were flattening out; Fig. 11); i.e. a large number of fishes would need to be trapped before a new species would be trapped for most cover types. The rarefaction curves for Marsh and DMM indicated that new species could be expected. Marsh had the highest species richness, with the greatest number of species trapped even though a higher number of individuals were trapped in other cover types. During the last quarter of trapping, two new species of fishes were trapped in DMM (Oscar and Spotted tilapia, both exotic cichlids), SDM (Spotted sunfish and Walking catfish), and P50 (Spotted sunfish and Spotted tilapia). No new species were trapped in P75 or Marsh.

Twenty seven species and 8,428 individuals of fishes were captured in drift fences. ANOVA was used to compare the average number of species and the average number of individuals trapped between cover types (Tab. 6). **There were no differences between cover types in the average number of species trapped** ($F = 1.389$, df = 4,10, $p = 0.306$). **However, there were higher average numbers of individuals captured in Marshes, P50, and P75, than in SDM, and DMM** ($F = 6.269$, df = 4, 10, $p = 0.008$; Fig. 12). This pattern of abundance of fishes may help to explain why the intermediate cover types were commonly used by foraging wading birds, and many fish-eating herptiles. The Shannon Diversity Index was not significantly different between cover types ($F = 0.438$, df = 4,10, $p = 0.779$, Fig. 12). There were no significant differences in the number of individuals, or species of exotic fishes found among the cover types (p's > 0.05; Fig. 13).

Sixteen of the 27 species of fishes showed clumped distributions. However, only seven species showed this clumping within a single cover type (statistical outputs included in Appendix III). The Bluefin killifish, Spotted sunfish and Oscar clumped in Marshes, the Florida gar and Spotted tilapia in P75, and the Pike killifish and Swamp darter in SDM. Each of the other taxa that showed clumped distributions, 9 of 16 (or 56%), were clumped in locations in more than one cover type. **Since only 7 of 27 species (26%) showed clumped distribution within a single cover type, variables other than melaleuca density were equally important in determining species abundance. These variables include variations in historical patterns of distribution, hydropattern, and access to deep water refugia.**

Cluster analyses of the data for fishes showed the three Marsh replicates tightly grouped together, but joined by a range of replicates from intermediate cover types, and even DMM. Four of the six dense melaleuca sites (DMM and SDM) clustered together with one P75 site (Fig. 14). This result demonstrated the wide overlap in fish community structure among the melaleuca gradient. In other words, most species of fish were found wherever there was standing water. For example, in Figures 15 and 16, six of the eight species distribution patterns shown, reveal common use of many cover types. However, two of the species show a cover type preference. Distribution of the Bluespotted sunfish was clumped in Marsh, and that of the Pike killifish was clumped in SDM.

As was the case for the macroinvertebrates, fishes, as a group, followed gradients of water more strongly than gradients of melaleuca coverage, at least through P75. **It is important to note that there was a lower abundance of fishes in dense melaleuca coverages. This translates into a lower forage base for many higher-level consumers** (e.g. many herptiles, wading birds, some mammals).

Amphibians and Reptiles

Amphibians and reptiles were trapped or observed in the five defined cover types by four standard methods (dip netting, minnow trapping, drift fencing, and faunal transects; Tabs. 3, 4, 5-6, and 7, respectively) plus serendipitous incidental observations. During the two year study period, 38 species and 1,547 individuals were trapped or identified in the five defined cover types. The cumulative number of species found in each cover type ranged from 27 (SDM and Marsh) to 31 (P50). The cumulative number of individuals in each cover type ranged from 208 (Marsh) to 380 (SDM). An additional five species of reptiles were observed in the study area along levees, but were not trapped in any of the five defined cover types. These five species were: Gopher tortoise, Chicken turtle, Peninsula cooter, Brown water snake, and Rough green snake. These species will be discussed in further detail at the end of this section.

The most abundant amphibians found in the LBSA were the Southern leopard frog (256 individuals), Greenhouse frog (174 individuals), Oak toad (134 individuals), Pig frog (108 individuals), and the Greater siren (64 individuals). The most abundant reptiles were the Brown anole (180 individuals), Black racer (104 individuals), Florida green water snake (70 individuals), Florida water snake (70 individuals), and the American alligator (67 individuals).

Two species of non-native amphibians and one species of non-native reptile were trapped. All three species are typical of drier, ruderal or edificarian habitats (Duellman and Schwartz, 1957; Dalrymple, 1988). The Cuban treefrog (13 individuals) was trapped in P75, DMM and SDM. The Cuban treefrog requires standing water for its egg/tadpole stage, yet these stages are of short duration (two months). The Greenhouse frog (174 frogs) was trapped in 11 separate sites representing DMM, SDM, and P75 habitats. However, 87% of these frogs were trapped at just two sites (109 frogs at a SDM site and 42 frogs at a DMM site). The Greenhouse frog has no aquatic egg/tadpole stage. The Brown anole is highly tolerant of disturbed settings (Wilson and Porras, 1983). It was most abundant in DMM (83 lizards from 5 sites) and SDM (38 lizards from 4 sites), although it was trapped in all cover types (180 lizards total across all habitats).

Thirty-four species and 1,265 individuals of herptiles were captured in drift fences. ANOVA was used to compare the average number of species and the average number of individuals trapped between cover types (Tab. 6). **There were no significant differences between cover type in the average number of species** ($F = 2.08$, $df = 4,10$, $p = 0.16$), **average number of individuals** ($F = 1.40$, $df = 4, 10$, $p = 0.30$), **or Shannon diversity** ($F= 0.710$, $df = 4, 10$, $p = 0.603$; Fig. 17).

Rarefaction indicated that the number of species trapped was at expected levels (all Cover types have current values that exceed the expected value from rarefaction from Everglades National Park prairies, Dalrymple, 1988). Furthermore, all cover types yielded very similar curves when their rarefaction curves were calculated (Fig. 18). During the last quarter of trapping, no new species of herptiles were trapped in any of the cover types. It is predicted that new species would be trapped at a very low rate.

Eighteen of the 34 species of herptiles (54%) showed clumped distributions. However, only six species showed this clumping within a single cover type (statistical outputs in Appendix III). The Striped mud turtle and the Southern toad clumped in Marshes. The Eastern garter snake and the Southeastern five-lined skink clumped in P75. The Brown anole and Green treefrog clumped in DMM. The other 12 taxa that showed clumped distributions, clumped in locations in more than one cover type. In other words, a species clumped in a marsh site, as well as a site representing any one of the other four cover types. **Since only 6 of 34 species (18%) showed clumped distribution within a single cover type, this indicated that variables other than melaleuca density were also important in determining species abundance. These variables include variations in historical patterns of distribution, hydropattern, and access to either deep water refugia or high ground refugia.**

When the numbers of individuals of each species were placed in a correlation matrix by cover types for multivariate analyses, the sites that shared similar species composition were easily identified. In the cluster analysis by cover types, Marsh separated out with one of the P50. The other two P50 grouped with the P75. The SDM and DMM separated as a third distinct group (Fig. 19). When the same matrix was analyzed by species composition, the Pig frog, Striped mud turtle, Florida green water snake, Striped crayfish snake, and Cricket frog all clustered together as good indicators of Marsh conditions. The majority of snakes, lizards, frogs, toads and lizards used the wide range of intermediate cover types (P50 and P75). This included fully aquatic species such as the Mud snake, Two-toed amphiuma, Southern leopard frog, and Florida banded water snake. The non-native Cuban treefrog, Greenhouse frog, and Brown anole, together with the native Eastern narrow-mouth toad, Oak toad, and Greater siren grouped together in DMM and DMS. As was the case for fishes, many herptiles demonstrated overlap in community structure along the melaleuca gradient. For example, in Figures 20 and 21, five of the eight species distribution patterns shown, reveal common use of many cover types. However, three of the species show a cover type preference. Distribution of the Striped mud turtle was clumped in Marsh. The Striped crayfish snake showed preference for Marsh and P50. The Greenhouse frog very abundant at two sites (a SDM and a DMM), yet absent from most sites.

The presence of so many Greater sirens in DMM and DMS habitats was unexpected. This salamander is fully aquatic, and, is unable to feed out of the water. It would quickly die from desiccation on dry land. It was trapped at 11 of the 15 drift fence sites. Twenty-two of the 60 Greater sirens trapped by drift fencing were trapped in one DMM site (Tab. 6). This site was located along the northern edge of the LBSA, isolated from areas of lower melaleuca density. This animal has a rather limited home range and individuals were trapped as soon as standing water levels existed. Four individuals were trapped at this site two days after heavy rain resulted in flooding of this site. A fifth, large individual was trapped on the third day following flooding. This indicated some unidentified subterranean refugia near the trapping sites. Another 11 Greater sirens were trapped at one SDM site (Tab. 6). Refugia for this species are known to be subterranean moist soils, where they aestivate in a mucus covering (Bishop, 1962).

Factor analyses (of raw data and data transformed as percent composition; Fig. 22) also identified the same separation of species by habitat preference. Both the cluster and factor analyses of the cover types revealed the same pattern. Marsh factored out as a distinct group at one extreme, with a gradient extending from P50 to SDM and DMM (Figs. 19, 22). The same matrix was analyzed for the loadings of the taxon on the first two principal components (Fig. 23). The loadings showed a broad scattering. Taxa at one extreme (left side of graph) were typical of Marsh and P50. Taxa at the other extreme (right side of graph) were typical of DMM and SDM. The taxa with significant clumped distributions were outlined (Fig. 23; I index p's < 0.025).

In addition to the 34 species of herptiles trapped by drift fencing, an additional 4 species were noted in at least one of the five defined cover types by other methods (total of 38 species in defined cover types). Three species of herptiles were observed only during faunal transects (American alligator, Florida softshell turtle, Florida redbelly turtle, Tab. 8). The size of these species made it very unlikely that they would be trapped by drift fencing. A fourth species, the Yellow rat snake, was noted in DMM as an incidental observation. The individual was seen in the branches of a melaleuca tree, approximately three meters above the ground. The Yellow rat snake is highly arboreal, hence rarely traps. Each of the four species noted above were also observed during road surveys (Tab. 10).

In addition to the 38 species of herptiles observed in the five defined cover types, five other species were seen only along levees during road surveys in the LBSA (Tab. 10). Three of these five species would be likely to survive in the seasonal wetland habitats of the LBSA, yet their life histories would make them difficult to trap. The Chicken turtle and the Peninsula cooter are large aquatic turtles that are rarely trapped by drift fencing. The Rough green snake is highly arboreal and therefore, also unlikely to be trapped by drift fencing. The Gopher tortoise, a Species of Special Concern, was observed once along a levee at the southern end of the study area. The shell of this individual was marked with blue paint, suggesting the animal was at one time held in captivity. The historical distribution of the Gopher tortoise in southern Florida would have included sandy pinelands in the eastern portion of Dade County. However, the LBSA does not include habitats suitable for maintaining a population of Gopher tortoises. A Brown water snake was observed along a levee adjacent to a canal. This species prefers deeper riverine waters (e.g. canals). It is probable that it would at least seasonally use wetland habitats in the study area.

Four species that were expected to occur in the LBSA were never observed. Two of these, the Eastern indigo snake (*Drymarchon corais*) and the Eastern diamondback rattlesnake (*Crotalus adamanteus*) are large, upland species. Their absence indicated that not enough continuously dry land exists in the area to support populations. Two other species, the Dusky pygmy rattlesnake (*Sistrurus miliarus*) and the Florida brown snake (*Storeria dekayii*) are both smaller snakes. These species are typical of seasonal wetlands and are commonly seen over most of rural Dade County. The Dusky pygmy rattlesnake, when present, is normally very abundant and commonly seen. Its absence indicated that the area may have too little dry land to support populations.

<u>*Birds*</u>

Birds were observed in the five defined cover types by two standard methods (faunal transect and fixed length strip transects; Tabs. 8 and 9, respectively) plus serendipitous incidental observations. During the two year study period, 48 species and 614 individuals were identified in the five defined cover types. The cumulative number of species found in each cover type ranged from 17 (Marsh and DMM) to 30 (P75). The cumulative number of individuals in each cover type ranged from 39 (DMM) to 163 (P75). An additional 44 species were observed along roadways and levees in the study area. These will be discussed in further detail below.

The most abundant species observed in the LBSA were the Great egret (593 birds), Little blue heron (348 birds), Meadowlark (174 birds), Great blue heron (173 birds), and the Red-winged blackbird (166 birds).

ANOVA could not be performed to test for significant differences in the average numbers of species and individuals between cover types since the data were collected from randomly selected sites.

When the strip transect data was analyzed as twenty-four month cumulative data, 518 individuals of 46 species were observed across all five cover types (Tab. 9). P75 had the highest number of species (29) and the highest number of individuals (146; Fig. 24). DMM had the lowest number of species (9) and individuals (39). Marsh had the second highest number of individuals (137) yet had a lower number of species (15) than SDM, P75 and P50 (22, 29, and 27 species, respectively). Shannon Diversity was highest in SDM and lowest in Marsh (Fig. 24). Lower diversity indicates that a lower number of species accounted for most of the individuals. Evenness was also highest in SDM. It was lowest in P75. Lower evenness indicates that some species were abundant, while others were rare (Odum, 1983).

Species in P75 were a peculiar mix of typical wetland/prairie species and upland species. Species observed in DMM were characteristic forest/edge species. Species observed in Marsh were typical of Everglades wetlands (herons, egrets, Red-winged blackbird, Eastern meadowlark, and Common yellowthroat; Robertson and Kushlan, 1984).

The rarefaction curves of all cover types still showed an upward trend, indicating that maximum species richness was not sampled after 24 months (Fig. 25). The numbers of new species recorded in each Cover type during the eighth quarter were: DMM, 0 species; SDM, 1 species; P75, 1 species; P50, 1 species; Marsh, 1 species.

Fifteen of 46 species of birds observed during transects showed clumped distributions. Unlike the patterns seen in macroinvertebrates, fishes and herptiles, most species (11 of 15 or 73%) clumped in a single cover type (statistical outputs available in Appendix III). The Common yellowthroat, Common snipe and Red-winged blackbird clumped in Marsh. The Eastern phoebe and Boat-tailed grackle clumped in P50. The Northern flicker, Northern mockingbird, Yellow-rumped warbler, and Prairie warbler clumped in P75. The American redstart and Rufous-sided towhee clumped in SDM. The remaining species clumped in adjacent seral stages. The fifteen species (33% of total species) that had clumped distributions accounted for 76% of all individuals observed in transects (395 of 518). Many species did not show a clumped distribution simply because they occurred only a few times (e.g. House wren, Swamp sparrow). **For 11 of the 15 species that showed a clumped distribution, clumping occurred within a single cover type. This indicated that cover type, defined by degree of melaleuca density, was important in the distribution of the many bird species.**

Since the data were collected from three randomly selected sites in each cover type for each month, the data was combined for each cover type. The resultant matrix for multivariate analyses was a 46 (species) x 5 (cover type) matrix.

Cluster analysis demonstrated that the species composition of the cover types was dramatically different (Fig. 26). **Common yellowthroats (57 individuals), and Red-winged blackbirds (47) were characteristic of Marsh.** These two species are resident breeding species, typical of marsh habitats. They accounted for 76% of all individuals seen in Marsh habitats during transects. **The DMM sites were characterized by the presence of Carolina wren and Bluejay.** The plots of numbers of individuals of Common Yellowthroat and Carolina Wren by cover type were essentially the opposite of one another (Fig. 27). **The majority of herons, egrets, perching birds, loggerhead shrikes, raptors, and woodpeckers used P50, P75,**

and SDM. These cover types had the most species represented, but no more individuals than the marshes.

Of the 46 species observed during transects, 29 were resident species and 17 were wintering species (see Appendix IV for listing of resident versus wintering species). **The percentage of individuals that were resident species was highest in Marsh (93%) and lowest in SDM (49%; Fig. 28).** Most migratory species were warblers, which favor forested areas (Morse, 1985).

The strip transect method used in this study targeted bird species with small daily cruising radii, which selected habitat based primarily upon vegetative cover (e.g. passerines, some raptors), not standing water conditions (e.g. many wading birds). Yet wading birds are frequently given high profile in wetland assessments in southern Florida. Again, sampling methods in this study were intended to provide gross information on all species. Wading birds observed during transects were generally solitary, foraging individuals. Wading bird use of the habitats other than the five defined cover types will be discussed below.

In addition to strip transects, bird abundances (especially wading birds) along levees in the LBSA were evaluated during road surveys. Overall, 2,780 individuals of 72 species of birds were observed during monthly road surveys (Tab. 10). Forty-four of these species were not observed in any one of the five defined cover types. Several factors contributed to higher species counts during road surveys versus strip transects. Road surveys covered a much longer distance, and crossed a variety of cover types as well as edges of cover types. Many raptors and warblers prefer edge habitats. Additionally, secretive species were detectable from a distance along the roadway. This included King rails, Pied-bill grebe, and American coots. These species would be expected to use marsh habitats, but their behavior of quietly moving away rather than flushing makes them difficult to detect on foot in dense vegetation. Wading and shore birds were frequently observed along the Dade-Broward Levee and the FPL R/W.

During some months, mixed flocks of 50-240 wading birds were observed foraging in the shallow water impoundments along the FPL R/W, particularly south of the Pennsuco Canal (Fig. 29). While a number of juvenile wading birds (White ibis, Little blue heron, Wood stork) were observed foraging in the area, their presence was not considered to indicate breeding populations in the LBSA for two reasons. Firstly, there were no direct observations of nesting. Nesting typically occurs in large tree islands. While these habitats occurred in the study area, they were located such that either an airboat or aircraft would be necessary to survey them. This was beyond the scope of the project. Secondly, there are several traditional breeding rookeries for wading birds in the eastern portion of Water Conservation Area (WCA) 3B (1987, 1988, 1989 aerial surveys), approximately 8 km east of the western boundary of the LBSA (Fig. 30; modified from Runde et al., 1991). Wading birds have daily cruising radii from roosting to foraging sites of up to 35 km (Frederick and Collopy, 1988).

Four species of non-native birds were observed along levees or canals in the study area. Each of these species is considered to have established a self-sustaining breeding population (Robertson and Woolfenden, 1992). All are more common in suburban and ruderal settings than in natural habitats (Robertson and Woolfenden, 1992). The European starling was observed both summers, nesting in electric poles along the FPL R/W. Muscovy ducks were observed along canals. A single Budgie was observed along Dade-Broward Levee. The Eurasian collared-dove was observed along levees.

Serendipitous observations of nesting occurred during the two years. Two Carolina wren nests were found. One nest was located in the peeling outer bark of a mature melaleuca tree in DMM cover type (Fig. 31). The second nest was located in a pile of minnow traps stored in the fork of a sapling melaleuca tree in a SDM cover type. A Ground dove nest was located in a clump of muhly grass (*Muhlenbergia capillaris*) in P50 (Fig. 31). A single Red-winged blackbird nest was found constructed in the fork of a melaleuca tree in P50. A Killdeer nest and a Common nighthawk nest were located along gravel levees. Both species nest on the ground, frequently in areas with sparse vegetation. Additionally, juveniles of several known breeding species were seen in the company of adults. This indicated that these species were also breeding in the area, since groups of juveniles and adults would not be seen far from the nesting site. These species included Northern cardinal, White-eye vireo, Red-winged blackbird (many juveniles seen), and King rail. This summary of birds breeding within the study was not intended to be a complete list of breeding species. It included only those species directly observed nesting or with juveniles.

Numerous melaleuca trees with woodpecker cavities were located. Cavities are used year-round for roosting, not solely for nesting. The Red-bellied woodpecker was most frequently observed in DMM, DMS, and P75 while the Northern flicker was observed in P75, P50, and along levees. It was never observed in DMM or DMS. Flickers are known to prefer open areas, since, unlike most woodpeckers, they will forage on the ground (Erhlich et al., 1988). In Long Pine Key, Everglades National Park, five flicker nest cavities were located in pine trees within 150 meters of short-hydroperiod finger glades (Lewis, 1994). Melaleuca snags frequently had several excavations, stacked one on top of the other (Fig. 31). Generally, the upper cavities were only partially excavated. A number of cavities were located within 1.5 meters of the ground surface.

Raptors, especially Red-shouldered hawks, were commonly seen perched on the edges of dense melaleuca stands along levees and the FPL R/W. On several occasions, Red-shouldered hawks were observed eating a snake. Ospreys were commonly seen foraging along canals and the shallow water impoundments along the southern portion of the FPL R/W. American kestrels were abundant during the winter. They were most frequently seen along the FPL R/W, perched on a wire.

Loggerhead shrikes were common along the DB Levee, but were also observed perched in melaleuca trees in Marsh, P50, P75, and SDM. Loggerhead shrikes were abundant

<u>Mammals</u>

Mammals or mammalian sign (track/scat) were trapped or observed in the five defined cover types by three standard methods (faunal transects, bait and scent stations for medium to large mammals, live-trapping for small mammals; Tabs. 7 and 10, respectively). During the two year study period, 16 species and 195 individuals were trapped or identified in the five defined cover types. The cumulative number of species found in each cover type ranged from 7 (Marsh) to 14 (DMM). The cumulative number of individuals in each cover type ranged from 24 (Marsh) to 45 (P50 and DMM). Additional observations of mammals were made along levees in the study area. While no additional species were noted along levees, they were the most common place to see medium (Raccoon, Gray fox) and large mammals (White-tailed deer).

Five species of non-native or domesticated mammals were observed. Dogs were the most common domesticated mammal seen (26 occasions), and were observed throughout the study area. Domestic cats were seen along a levee, approximately one mile from a residential area. Two non-native rodents (Black rat and House mouse) were trapped in a DMM site that was located between agricultural and residential areas along Krome Avenue. These two species are uncommon in natural habitats isolated from developments. Nine-banded armadillo was common during the first year in DMM and SDM sites. This species is well-established throughout Florida (Layne, 1976).

The only mammal to show a significantly clumped distribution was the Nine-banded armadillo, which was most common in DMM (Fig. 32; statistical outputs in Appendix III). For all other mammals, the data sets were either too small (e.g. many of the small rodents, and shrew) or the species did not showed a clumped distribution. White-tailed deer, Raccoon, Virginia opossum, and Bobcat ranged throughout the study area, regardless of melaleuca density. **This indicates that cover type was not as important in the dispersion of the species as were other variables, including standing water.** The River otter was strongly associated with marsh, but the sample size was too small to yield a significant clumped distribution. This was the only mammal species observed in the LBSA which is fully dependent upon wetland habitats.

Dry ground refugia, including trees, were especially important to many of the mammal species in the area. This is critical in terms of future planning. **Retention of the mammalian fauna of the area requires planning for dry ground refugia and water-dry land interfaces of sufficient acreage to permit persistence of mammal populations.**

Continuous high standing water levels limited the use of bait and scent stations and searches for sign (tracks or scat). At most, species list by cover type can be generated.

Nine-banded armadillo sign was common in DMM. Individuals were frequently seen along levees. Virginia opossum and Raccoon tracks were noted in all cover types. Raccoons were the most frequently seen mammal. Each of these species are abundant and common throughout their ranges.

Marsh rabbit tracks and scats were observed in all cover types. On two separate occasions, scat was found on top of a drift fence funnel trap when sites had standing water. Bobcat tracks were noted in P50, P75, SDM and DMM. On one occasion in February 1995, a Bobcat was seen walking along the FPL R/W. Gray fox tracks were observed in P75, SDM and DMM. Additionally, a Gray fox was seen on a levee, in the same general area, three separate times during one week in December 1994. On each occasion, the fox disappeared into sites with dense sapling melaleuca. A Gray fox was also seen along a trail in a DMM site. Gray Fox prefer habitats with dense vegetative cover and are known to seek refuge in trees.

In 1994, a River otter was seen on two occasions along the east-west portion of the Wellfield Canal and once along the Dade-Broward Levee. In both sightings along the Wellfield Canal, the River otter was seen crossing from an area with approximately 50% melaleuca coverage into the Wellfield Canal. River otter tracks were noted in Marsh, and scat were occasionally found along the Dade-Broward Levee.

White-tailed deer were seen on several occasions along the FPL R/W and the Dade-Broward Levee. Tracks were seen in each of the five cover types during the dry season. Two does were once seen in the Pennsuco wetlands. Both bucks and does have been seen. It is estimated that the area could support a maximum of 12 to 15 deer. The most recent deer sighting occurred during October 1995, when two does were seen three separate times during one week.

The Hispid cotton rat was trapped in P50, P75, and SDM, the Marsh rice rat was trapped in all cover types, and the Cotton mouse in SDM and DMM (Tab. 11). The cover type/habitat preferences of these three rodents observed in this study are similar to trapping results in mature dense melaleuca versus "mixed melaleuca-graminoid" (Mazzotti et al., 1981) and tree islands surrounded by sawgrass marsh (Smith and Vriese, 1979).

Red imported fire ants (RIFA)

The abundance of RIFA mounds was quantified on a quarterly basis (Tab. 12). The highest number of ground active mounds was found in P75, followed by P50 (Fig. 35). Ground active mounds were rare in DMM (1) and absent in Marsh. Fire ants avoid shaded conditions (such as close-canopy DMM cover type) as well as areas of high soil moisture content (such as the Marsh covertype). During five of the eight quarters, each of the randomly selected Marsh sites had standing water. During periods of standing water in the P50, P75 and SDM cover types, it was noted that at least some of the mounds moved into the bark of melaleuca trees.

Ground active fire ant mounds are known to have a detrimental effect on ground dwelling birds, such as Bobwhite quail, indirectly by affecting insect populations (Allen et al., 1993 and 1994). The effect of RIFA on other ground dwelling animals has not been well documented. However, on several occasions, we noted small herptiles (Oak toad, Southeastern five-lined skink, Red rat snake) devoured by RIFA. We also observed that RIFA mounds relocated into the bark of the melaleuca trees during periods of standing water. Of 83 trees surveyed in three separate P50 and P75 sites with standing water, 31 of the trees had active RIFA mounds in the bark. During this survey, we also observed a Southeastern five-lined skink, a Green anole, a Green treefrog and a Squirrel treefrog in the peeling bark of melaleuca trees. The fact that both RIFA and small herptiles seek refuge in melaleuca bark during periods of high water may diminish the ability of small herptiles to survive periods of high water.

TWENTY-FOUR MONTH CUMULATIVE RESULTS

When all sampling methods and incidental observations were considered, a cumulative number of 23,525 individuals of 160 species of **invertebrates and vertebrates** were trapped or observed in the five defined cover types during the 24 months of the study. Fishes accounted for 46% of all individuals (10,708 individuals of fishes). For the cumulative data set by cover types, the number of species and individuals, respectively, were:

Cover type	Species	Individuals
Marsh	94	4,936
P50	109	7,421
P75	115	5,121
SDM	103	3,555
DMM	98	2,492

Vertebrates have been the traditional classes of animals used in evaluating wildlife habitat value. Across all five cover types, 13,064 individuals of 129 species of vertebrates were trapped or observed during the 24 months of the study. For the cumulative data set by cover types, the number of species and individuals, respectively, of **vertebrate animals only** were:

Cover type	Species	Individuals
Marsh	73	2,664
P50	86	3,703
P75	88	3,259
SDM	84	1,841
DMM	79	1,597

The cumulative numbers of species and individuals of each vertebrate class are indicative of the species diversity of the study area relative to the southern Florida region. The cumulative numbers of species and individuals observed in all five defined cover types during the first 24 months of sampling were:

Class	Species	Individuals
Fishes	27	10,708
Amphibians	16	881
Reptiles	22	666
Birds	48	614
Mammals	16	195

The roadways, particularly the FPL right-of-way, levees and canals were frequently used by wading birds and larger aquatic vertebrates (turtles, alligators) that are less frequently trapped. Therefore the cumulative numbers of vertebrates observed or captured in the study area, including the defined cover types, roadways, levees and miscellaneous habitats, were pertinent:

Class	Species	Individuals
Fishes	30	10,737
Amphibians	16	942
Reptiles	27	983
Birds	92	3,678
Mammals	16	272

The FPL right-of-way, the mitigation areas along the Well field Canal, and the canals appeared to be focal points for birds, especially the duck-like swimmers, wading, and shore birds, using the region. Duck-like swimmers (coots and gallinules) use natural areas, but, since they quietly swim away rather than flush, it was difficult to detect the presence of these species on foot in dense vegetation. Furthermore, many smaller perching birds were detected using edges of DMM and SDM only during road surveys. Many of these species prefer thickets or edges.

<u>State or Federal listed species</u>

Species listed under either state or federal guidelines may require consideration in developing land use plans. The following species designations are current as of February 14, 1994 (Wood, 1994). Eleven listed species were observed in the LBSA (Tab. 13).

Endangered Species. The Wood stork is the only Endangered species observed in the LBSA. It is listed at both the State and Federal levels. Both adult and juvenile Wood storks were observed foraging in the shallow water impoundments along the FPL R/W, mitigation areas along the Dade-Broward Levee, and in P75. The highest number of individuals observed in one day was 53. These individuals were in a mixed species of flock of more than 300 wading birds foraging along the FPL R/W in April, 1995. The closest breeding rookery (1989 data) is located approximately 15 km to the west of the Lake Belt Study Area, on the eastern border (L67) of WCA 3A (Bancroft et al., 1990; Runde et al., 1991). This colony supported 125 nesting pairs of Wood storks. It also supported Great egrets, Snowy egrets, Tricolored herons, Little blue herons, and White ibis. Total number of active nests was estimated to be more than 2,000 (Bancroft et al., 1990).

Threatened Species. The American alligator was the only species listed as Threatened (Similarity of Appearance) at the Federal level that was observed. The alligator is listed as a Species of Special Concern at the state level (see definition below). It is listed at the federal level due to similarity of appearance to declining populations in the northern part of its range. The alligator was regularly observed in canals. Trails were frequently seen in P50 and Marsh. Four individuals that had been killed by gunshot were found. One of the animals had its tail removed. The Least tern is listed at the State level, but does not have any designation at the Federal level was seen on several occasions, foraging above a canal.

Other State Listed Species: Species of Special Concern. The State of Florida designates populations that are not currently Threatened or Endangered within the state yet have shown long term population declines and are considered either vulnerable to exploitation or environmental changes as Species of Special Concern (SSC).

Seven species listed as SSC have been observed in the LBSA. These species are: American alligator, Gopher tortoise, Snowy egret, Tricolor heron, Little blue heron, White ibis, and Roseate spoonbill. The American alligator was discussed above under Threatened Species. A single Gopher tortoise was found along a levee. The individual had been marked with paint, suggesting that it had been held in captivity. Suitable habitat for this species does not exist in the LBSA. The occurrence of this individual is anomalous. The remaining five species of wading birds seasonally forage within the LBSA. Traditional breeding rookeries are located to the west of the LBSA in Water Conservation Area 3A and 3B.

Other Federal Listed Species: Candidates (C1 and C2) and Under Review (UR). The US Fish and Wildlife Service designates species that are considered vulnerable as candidate species. Species for which there is sufficient evidence to warrant either Endangered or Threatened status are designated as C1. Species considered vulnerable yet requiring additional evidence to determine population status are designated as C2. Candidate species are not protected under the US Endangered Species Act. However, the USFWS "encourages their consideration in environmental planning" (US FR Vol 55, No. 35, pp. 6184-6229).

Three species designated C2 have been observed. These species are: Gopher tortoise, Island glass lizard, and Loggerhead shrike. The Gopher tortoise was discussed above as a State of Florida Species of Special Concern. The Island glass lizard was trapped on nine separate occasions in P50 and P75. This species does not have any designation at the State level. The Loggerhead shrike is a winter resident bird. It was observed in Marsh, P50, P75, SDM and along levees. This species does not have any designation at the state level.

Numbers of native and non-native species

During the 24 months of the study, 2,452 individuals of 20 species of non-native vertebrates were trapped or observed within the study area, including areas other than the five defined cover types. Eight of these 20 vertebrates were fishes (Black acara, Jewelfish, Pike killifish, Spotted tilapia, Oscar, Nicaraguan cichlid, Walking catfish, Peacock bass). We list the Peacock bass an a non-native species, yet this species is recognized by the Florida Game and Fresh Water Fish Commission as a game species and is a regulated species. Of the remaining 12 species, 5 were mammals (Black rat, Domestic cat, Domestic dog, House mouse, and Nine-banded armadillo), 4 were birds (Budgie, Muscovy duck, Eurasian collared-dove, European starling), 1 was a reptile (Brown anole), and 2 were amphibians (Cuban tree frog and Greenhouse frog). All but one of these non-native species are "Wetland Independent". The Cuban treefrog is the only non-native species which is "Seasonal Wetland" and has been trapped in DMM, SDM and P75.

When only the five defined cover types were considered, 2,377 individuals of 15 species of non-native fishes, amphibians, reptiles, birds, and mammals. The five species found only along levees were Peacock bass, Budgie, Muscovy duck, Eurasian collared-dove, and European starling. **The percentage of the 24 month cumulative numbers of species and individuals that are non-native was highest in DMM and SDM (Tab. 14).** The most abundant non-native animal was the Jewelfish (cichlid fish, 1,083 individuals), followed by the Black acara (cichlid fish, 686 individuals), Greenhouse frog (174 individuals), Brown anole (170 individuals) and the Pike killifish (111 individuals).

Habitat preference and species composition

Gross comparisons of the numbers of species or numbers of individuals found in each cover type did not yield significant differences among the cover types. However, multivariate analyses, which considered the contribution of each species to overall community composition, demonstrated differences between cover types. Indices of dispersion indicated that many faunal groups were distributed along a gradient other than melaleuca density. To assist in evaluating community composition in terms of hydrology, each species was categorized based upon their requirement for a particular, gross hydrologic pattern.

Macro-invertebrates and fishes were excluded from the wetland association analyses for two reasons. Firstly, most taxa in these groups are wetland dependent. Since large numbers of macro-invertebrates and fishes were trapped relative to all other faunal groups, their inclusion would swamp the analyses. Secondly, macro-invertebrates and fishes usually showed a positive correlation between the number of species and water levels. The objective of these analyses was to determine the relative quality of habitat based on the degree of melaleuca invasion, not water levels. Therefore, species groups that showed significant positive correlations with rising water level were more likely to confound the effects of melaleuca invasion and current hydrological patterns. In other words, it could be said that high numbers of species and, or individuals were related more to water levels than melaleuca density.

For the purpose of the analysis, species whose respiration, feeding mechanisms, reproduction or larval development require 9 to 12 months of standing water each year were termed "**wetland dependent**". Species whose respiration, feeding mechanisms, reproduction or larval development require 1 to 9 months of standing water each year were termed "**seasonal wetland**". Species whose respiration, feeding mechanism, reproduction or larval development are independent of standing water were termed "**wetland independent**". Animals described as "wetland dependent" or "seasonal wetland" use upland habitats, but a population could not persist without suitable wetland habitat. Conversely, animals described as "wetland independent" use wetland habitats, but their life history traits allow them to survive and successfully breed outside of wetlands. The current assigned wetland association of each species of amphibian, reptile, bird and mammal is listed in Appendix IV. **Macro-invertebrates and fishes were excluded from the analyses.**

When the 24 month cumulative data for all sampling methods were considered, the occurrence of "wetland dependent" and "seasonal wetland" species of amphibians, reptiles, birds, and mammals was highest in Marsh (0% to 10% melaleuca) and lowest in SDM and DMM (75% to 100% melaleuca, either sapling or mature). In Marsh, wetland associated species accounted for 76% of the species and 91% of the individuals trapped or observed (Tab. 15). SDM and DMM had the lowest percentage of wetland associated species (42% and 41%, respectively) and individuals (44% and 44%, respectively). Observed vs. expected numbers for wetland and non-wetland individuals and species per cover type both showed significant differences. **There**

were fewer wetland and more non-wetland species occurring in the SDM and DMM cover types (chi squares = 75.23 and 245.17, df = 4 and 4, p's < 0.0001, respectively; Fig. 36).

The numbers of wetland dependent and seasonal (y-axis) versus numbers of non-wetland animals (x-axis) were plotted for each cover type (Fig. 37). Regardless of whether the graphical analysis considered numbers of species or individuals of wetland versus non-wetland taxa, the patterns were the same. As succession moved from Marsh to P50 and P75, there was a curvilinear (negative exponential) trend for increased numbers of non-wetland species without a decrease in numbers of wetland species. Once melaleuca density went above P75, wetland associated taxa decreased in both number and abundance. This indicated that the loss of wetland species habitat value did not occur until melaleuca density caused canopy closure (e.g. above 75% melaleuca coverage). The point at which the number of species or individuals of terrestrial taxa was equal to the number of wetland taxa was demarcated on the figures as straight lines from the origin of the graphs. This point was reached at or near P75, i.e. melaleuca densities of 75%. The trend of increased species diversity was typical of intermediate stages in disturbed or degraded ecosystems (Odum, 1983).

It is important to recognize that species categorized as "wetland dependent" or "wetland seasonal" may require dry areas or have a preference for water depth. In fact, most wetland-associated vertebrate animals are adapted to using water depths of less than 25 cm (Fredrickson and Laubhan, 1994). Breeding densities of typical marsh bird species have been correlated with standing water levels in other areas of the birds' ranges. Both the Common yellowthroat and the Eastern meadowlark generally have higher breeding densities when climatic conditions indicate low standing water levels during the breeding season (Cody, 1985). Similar information regarding Red-winged blackbird breeding density and water levels was not available. However, since it commonly forages on the ground, it would follow a similar trend. Summer peaks of breeding Common yellowthroats, Red-winged blackbirds or Eastern meadowlarks were less obvious in 1995 compared to 1994 (Fig. 38).

Wading bird use of the LBSA

Wading birds were most frequently seen during road surveys. Several wading bird rookeries exist in the eastern portion of Water Conservation Area 3 (Fig. 30). Wading birds appear to locate appropriate areas for foraging quickly, even at distances from roosting sites (Fredrickson and Laubhan, 1994). Average distance traveled daily from a rookery to suitable foraging habitat is approximately 10 km, but may range up to 35 km (Frederick and Collopy, 1988). Water depth appears to be one of the critical determinants for selecting foraging habitat. Smaller egrets and herons (Snowy, Little Blue) most effectively forage in water depths less than 15 cm; larger waders (Great Blue Heron, Great Egret) selectively forage in 15 to 30 cm of water (Fredrickson and Reid, 1986). Species breeding in these rookeries included the Great egret, Green heron, Great blue heron, and Anhinga (Runde et al., 1991).

With the exception of the Great blue heron, herons and egrets preferentially nest in willows. Additionally, most rookeries are surrounded by water, which apparently reduces nest predation by terrestrial mammals and snakes (Frederick and Collopy, 1988). There were only a few suitable willow heads in the LBSA large enough for a breeding colony. One of these was located at the junction of the Pennsuco Canal and the Dade-Broward Levee. Congregations of Black-crowned night herons were noted during the spring at this site. However it was not clear if a breeding rookery was established.

Great blue herons tend to nest alone or in groups of a few pairs. This species has been reported to nest in melaleuca trees (Frederick and Collopy, 1988). Anhingas have also been reported to nest in melaleuca heads surrounded by sawgrass marshes (Schortemeyer et al., 1981). Nesting attempts in melaleuca trees by Great blue herons or Anhingas were not observed in the LBSA.

SUCCESSIONAL TRENDS

Successional changes in vegetative structure and faunal implications

Melaleuca invasion of native prairies changes the vegetational structure of the landscape. It is unclear to what extent melaleuca invasion also changes the hydrological characteristics of an area. This study was designed to address only the impact of melaleuca coverage on wildlife diversity and abundance. Prior to the current study, the only information available was based upon either dense melaleuca stands only (Schortemeyer et al., 1981) or were short-term studies that considered only a few species (Mazzotti et al., 1981; Sowder and Woodall, 1985 Repenning, 1986).

As melaleuca coverage increases, a graminoid prairie with low structural diversity becomes a savannah (mix of open prairie and trees) with increased structural diversity. As melaleuca coverage continues to increase, the savannah becomes a closed canopy forest with sparse understory. Since little understory persists in the forest and most of the trees are of similar size, structural diversity of the forest is lower than existed in the savannah stage of melaleuca invasion. Some animals (e.g. many birds, c.f. Cody, 1985) select habitat based upon subtle differences in vegetational structure. However, other animals (e.g. amphibians and reptiles) are less sensitive to vegetative structure but select habitats based upon other characteristics (e.g. soil or hydrological characteristics; Campbell and Christman, 1982).

The results of this study demonstrated a higher diversity and abundance of birds in the cover types that have moderate levels of melaleuca coverage. As discussed above, these were the cover types with the greatest structural diversity. Notably absent from these areas, though, were resident bird species which are specific about the types of trees they use (e.g. Pine warbler). Many of the transient and winter-resident birds occurred at much lower abundances than in cypress swamps of the Big Cypress National Preserve or the uplands of Long Pine Key, Everglades National Park (GHD, personal observations).

In contrast to the birds, a similar diversity of amphibians and reptiles was found across all cover types. However, their abundances generally decreased in the closed-canopy melaleuca forest (DMM cover type). The lower abundances indicated poorer habitat quality. This was probably the result of the closed-canopy of the forest limiting the amount of sunlight reaching the water surface. With reduced sunlight, the algae forming the structure of the periphyton mat does not develop. Many species of amphibians and reptiles consume Crayfish, Grass shrimp, and smaller forage fishes, which depend upon a well-developed periphyton mat. However, complex patterns of hydrology, and gapping in forest canopy due to wind storms and fires permits light penetration and the persistence of productive pockets of aquatic life even within dense stands of melaleuca. Changes in both structural and wildlife diversity are summarized in Fig. 39.

Landscape effects

Melaleuca invasion of a graminoid marsh increases the patchiness of the habitat. An aerial view of the LBSA reflects the high degree of interspersion of vegetative cover types, particularly north of the Pennsuco Canal and along the southern border (C4 (Tamiami) Canal) *[In the final version of this report, Fig. 2 will be replaced by color plate of vegetation map produced by EAS Engineering and will be referenced at this point. Vegetation map was not available for inclusion in this report]*. Cover types for wildlife sampling and vegetation mapping were defined by percent coverage by melaleuca. The spatial scale on which melaleuca coverage is defined is critical. Shifts in abundance of many plant and wildlife populations relate to the degree of canopy closure as well as hydrology. The impact of seedling or sapling melaleuca, which has little or no canopy, differs from that of mature melaleuca trees with the same percent coverage. It was for this reason that the original cover types were modified to include two coverages of 75% to 100% melaleuca (sapling versus mature).

The mosaic of prairies with low to moderate infestations of melaleuca surrounding mature dense melaleuca stands may allow higher numbers of individuals and species to persist in, or seasonally use, mature dense melaleuca stands. However, this factor was not explicitly considered in sampling. The only variable considered was melaleuca coverage. Random sampling of three replicates of each cover type per month did not permit testing of any variable other than melaleuca coverage. Further studies should address the effect of site location on animal abundance.

While the mosaic of habitats may contribute to the abundance of animals (particularly fishes and semi-aquatic herptiles) in dense melaleuca sites, it is unlikely that the Pennsuco marshes on the western edge of the area were the sole source of fishes and some fully aquatic herptiles (e.g. Greater siren, Two-toed amphiuma). Levees subdivide the LBSA along both north-south and east-west axis. These levees are dispersion barriers to fishes, and some fully aquatic herptiles. Therefore, some species are confined to isolated sub-basins, which sustain local populations. Abundance of Greater siren in a DMM site isolated from areas with lower melaleuca coverages was a good example of this. The rapid rate at which fully aquatic herptiles and fishes exploited standing water in many sites indicated that deep water or subterranean refugia were available within each of the sub-basins.

Changes in species composition

The number of species (species richness) and the number of individuals (species abundance) are not, by themselves, a good measure of the environmental value of a habitat. Disturbance of natural communities typically results in an increase in species diversity as non-native, migratory and/or species uncommon to the natural community increase in numbers. A typical example of this was increased species diversity in areas with moderate levels of melaleuca coverage. This resulted primarily from native bird species atypical of graminoid prairies using the unnatural habitat created by melaleuca invasion. Which species are using a habitat and the manner is which they use the habitat (foraging, breeding) are more important to final evaluation of habitat quality (Stauffer and Best, 1980; Keller et al, 1993). A fair analysis of habitat quality would evaluate the types of species (e.g. wetland versus upland animals, native versus non-native), as well as their abundances.

As discussed earlier, the loss of wetland species habitat value did not occur until melaleuca density caused canopy closure (e.g. above 75% melaleuca coverage; Fig. 36, 37). The point at which the number of species or individuals of non-wetland taxa was equal to the number of wetland taxa was reached at or near P75, i.e. melaleuca densities of 75%. These graphs also demonstrated the non-linear rate of transition.

It is important to recognize that species categorized as "wetland dependent" or "wetland seasonal" may require dry areas or have a preference for water depth. In fact, most wetland-associated vertebrate animals are adapted to using water depths of less than 25 cm (Fredrickson and Laubhan, 1994). Species assigned to the same category may have different preferences with regard to timing, depth and duration of flooding. Fredrickson and Laubhan state (p. 645): **"No single wetland or wetland type will provide all the resources needed by a single vertebrate during all of its life-history stages or for all vertebrates adapted to wetlands. Thus, wetland complexes are essential for successful management.".**

There were two principal physical gradients in the Lake Belt Study Area environment: tree density and water levels. Tree density was a geographic gradient, with density varying primarily from east to west. Water level was primarily a temporal gradient, varying with seasonal rainfall.

The dominant characteristic of the faunal shifts along the gradient of increasing melaleuca coverage was increased numbers of upland, arboreal, and, or forest species, not the loss of wetland species. Analysis of the species that are most strongly tied to this gradient, indicated that degree of melaleuca cover causes original wetland habitat to become progressively suitable to non-wetland species at a faster rate, than it becomes unsuitable to wetland species. The result is a pattern of increasing species diversity and abundance through the intermediate cover types. Increasing use of areas by savannah and forest birds, and mammals plays a significant role in creating this gradient.

The dominant characteristic of the faunal shifts along the gradient of water level was seasonal variation in abundance of wetland species. The majority of fully aquatic species (the aquatic macro invertebrates, all the fishes, and some herptiles, birds, and mammals) did use habitat with increased canopy cover, primarily as an effect of standing water. The existence of this prey base (invertebrates and forage sized fishes, in particular) permitted higher consumers to use these habitats.

Canopy closure occurred when melaleuca cover increased beyond 75%. This reduced sunlight penetration to the understory, and therefore reduced primary productivity of the periphyton and submerged macrophytes. This had a dramatic effect on the primary consumers and detritovore macroinvertebrates (e.g. apple snails, crayfish), resulting in overall lower abundance and productivity in the understory. However, complex patterns of hydrology, and gapping in forest canopy due to wind storms and fires permits light penetration and the persistence of productive pockets of aquatic life even within dense stands of melaleuca.

While it has been anecdotally noted in the literature that melaleuca invasion causes secondary increase in ground surface elevation, we observed little evidence of this in the study area. As the previous brief hydrological assessment has pointed out, most sites in the study area were flooded regularly according to existing patterns of rainfall, topography, and water management. Therefore, we have no evidence at this time that the gradients identified in species patterns were due to a ground surface elevation gradient. The wide variety of upland animals found in the area appeared to regularly use levees, embankments, roadways, naturally elevated spots, and trees as high water refugia.

Percent similarity in species composition

Using the species composition of the Marsh cover type as a standard for comparison for the other designated cover types, the percent of the species for each faunal group in each cover type that was the same as the species found in Marsh was calculated. For fishes and herptiles the four cover types shared between 50 and 70 percent of the Marsh species in common. The mammals showed similarities in species overlap with Marsh from 40 to 65 percent. The birds showed the greatest difference in species composition among cover types, with between 20 and 30 percent overlap in species composition to Marsh (Fig. 40).

In general, as melaleuca invasion progressed the fishes and herptiles retained a high degree of constancy in community composition. The fishes and herptiles moved along a gradient primarily dictated by standing water levels. Since the area had a very limited variation in topography, these faunal groups appeared to move in and out of local areas as water levels shift due to variation in topography, regardless of melaleuca density. The birds showed the most dramatic shift from typical marsh inhabitants to progressively greater numbers of forest dwelling species. The mammals showed a progressive change from wetland to upland species as forest cover increased.

The percent of taxa that were found in each of the five cover types varied widely between faunal groups (Fig. 41). Eighty percent of the 10 invertebrate taxa trapped by drift fencing were found in each cover type. Only 2 of the 46 birds observed in strip transects were found in each cover type (Common yellowthroat and Palm warbler).

Multivariate analyses of changes in species composition

In order to clarify patterns of species use of the region, a large data set was developed based on the raw data sets. This large data set was constructed as a qualitative data set, i.e. presence/absence data entries (see methods section) of 133 taxa of macroinvertebrates, fishes, herptiles, birds, and mammals. The data set was empirically derived, i.e. it relied on actual recorded observations using standard methods rather than a subjective list of what should or might occur in a cover type. The data set was analyzed by cluster analysis, factor analysis and multidimensional scaling in order to determine what subsets of species best characterized cover types. These subsets drew species from all the taxonomic groups.

Cluster analysis of the 133 taxa's presence or absence in the five cover types using percent disagreement resulted in a tree diagram in which Marsh was first joined by an intermediate grouping of P50 and P75, and secondarily by the more distant grouping of SDM and DMM (Fig. 42).

The same pattern was seen in the plot of the first two principal components of the factor analysis (Fig. 43): a curvilinear pattern or gradient from Marsh through P50 and P75 to the dense coverages. Overall then, the gradients in community composition that were identified when each faunal group was analyzed separately were also seen when all faunal groups were analyzed simultaneously.

BIOLOGICAL CONSIDERATIONS IN DESIGNING A LAKE BELT PLAN

Natural lakes are absent from southern Florida below Lake Okeechobee, with the exception of Lake Traford, near Immokalee, in Collier County. Of the 3,191 named, natural Florida lakes, 88.6% are less than 200 acres, 8.2% are between 200 and 100 acres, and 3.2% are greater than 1,000 acres (Dickinson et al., 1982). Many of the existing rock-mined lakes are 200 to 300 acres in size, with the largest lake approximately 580 acres (data obtained through DERM). Most of the lakes proposed in the South Florida Limestone Mining Coalition (SFLMC) Lake Belt Plan are greater than 1,000 acres (data from map of plan presented July 1995). This makes it difficult to readily compare the community composition and dynamics of natural Florida lakes and lakes created by rock-mining.

The characteristics of the *existing* lakes and littoral zones are addressed in this and following sections. It is important to recognize that the major issues identified herein address the "Lake Belt Plan" proposed by the SFLMC at the Lake Belt Implementation Committee's Public Meeting in July 1995. This plan is a "working document" being evaluated by various government, public institutions, and the rock-mining industry. However, much of the substantive analysis and recommendations offered here deal with the scale of design important for maintaining biological values.

Many institutions evaluating the plan must be primarily concerned with how many acres of land become lakes, or how lakes affect water management. The following biological assessment is concerned with questions such as, "How does the size, shape, depth, and placement of lakes affect biological processes in and outside of the study area?" and, "To what degree can lakes and littoral zones replace or enhance local and regional biological communities and dynamics?". The evaluation and recommendations herein are intended to offer substantive information for a final study design that benefits the biological system.

The analyses and review of the literature are intended to identify features of a littoral and lake design that could enhance overall wetland value. The present situation should be interpreted as transitional to an improved long range design with improved ecotones between upland, shore and shallow habitat, and lakes. Comparison of the rock mined lakes and littoral system to natural systems is based on the review of Florida lakes by Williams et al (1985). Comparisons of the wetland characteristics of littoral and lake complexes draw heavily from reviews by Canfield and Hoyer (1992), Williams et al (1985), Fredrickson and Laubhan (1994), and the classic review by Weller (1982). (Bold face, italics, or underling were added to stress specific facts in the quotes used below).

In reviewing the dynamics and productivity of fisheries in Florida lakes, Williams et al (1985:56) state that **"In lakes, the principal habitat variables influencing fish populations are *basin morphology, lake trophic status, and development of rooted aquatic plant communities."* Numerous authors have identified this series of limnetic and littoral characteristics that are important in overall evaluation of lake systems.** A brief summary of findings is given below.

Lake basin morphology

In reviews of basin morphology, **mean depth, shoreline development, littoral zone slope, and surface area** are the most important factors affecting habitat availability.

The effect of **mean depth** of a lake was succinctly summarized by Williams et al (1985:57). "As shown in Table 3 [*included herein as Table 16*], the biomass of all groups of fish, especially sport fish, is higher in littoral areas than in open water. Most Florida lakes with mean depths of less than 30 feet (10 m) have abundant acreage of littoral habitat for fish production. Florida lakes with mean depths greater than 30 feet (10 m) are generally unproductive sinkhole lakes."

Shoreline development, littoral zone slope and littoral zone area are interrelated. Williams et al (1985:57-58) defined and discussed shoreline development as follows: "The technical term "shoreline development", as used here, refers to the extent to which lake shoreline departs from the shape of a circle. Lakes which are more nearly circular when viewed from above have low shoreline development, whereas lakes which are elongate or have numerous coves, peninsulas, and islands have high shoreline development. As shoreline development increases, the amount of ecotonal area increases. Ecotone occur where two habitats types, such as vegetated littoral zone and open water, meet. They are characterized by a higher diversity of organisms resulting from the greater number of habitat types available in close proximity to each other. It has been demonstrated that shoreline development (the ratio of lake shoreline to surface area) is positively correlated with total standing crop of fish and sport fish harvest in reservoirs. **Lake surface area influences fish populations by simply increasing the quantity of available habitat, thereby increasing the total standing crop and potential harvest of fish. However, as surface area increases, the standing crop of fish per unit of surface area typically decreases. This is due to a proportionally greater increase in limnetic [*open water*] versus littoral zone habitat."**

Williams et al (1985:76) discussed the question of impacts from actual physical land area lost or altered during human activities, emphasizing the impacts of dredge and fill operations in wetland setting. "First, dredging and filling in wetlands along lake shorelines permanently destroys habitat vital to biological productivity and fishery resources. Shallow vegetated areas of lake systems are extremely important to the production of sport and forage fishes by serving as breeding, nursery, and refuge habitat. For example in Lake Tohopekaliga, water depths less than 15 centimeters supported a standing crop of small forage fishes and centrarchids in excess of 115 kg/ha with numbers exceeding 44,000,000 fish/ha [Wegener et al, 1973]. Similarly, Moyer and Williams [1982] have shown that emergent littoral zone vegetation supports a standing crop of 677 fish food organisms/m^3 as compared with 2 organisms/m^3 in nearby littoral areas dredged for small boat navigation channels. Since fish and invertebrate populations are reduced in proportion to the amount of habitat lost, the standing crop of fish and fish food organisms in a lake will decline in numbers similar to those reported above. Because these numbers represent standing crop only, the loss in terms of annual productivity per unit of lake area can be expected to be considerably higher."

Comparison of estimates of standing crop of forage fish per unit area for open marsh systems vs. small constant depth littoral zones can be misleading. Moreover, the estimates vary widely, and are significantly affected by sampling methods, and hydrological conditions (see Loftus and Eklund, 1994). Part of the problem with simplistic comparison of forage fish standing crops is that they do not include information on the actual availability to consumers, e.g. foraging wading birds. Wading birds normally exploit forage fishes during periods of dry down, when the fishes are trapped in small puddles and pools of water at extremely high density. Such drying down currently does not exist for the rock mined lakes' littoral zones, which have a constant depth, and for which the adjoining deeper water of the lake can act as a temporary refuge from wading bird foraging. Canfield and Hoyer (1992:565-566) discussed lake characteristics with regard to wading bird use and state: "Because these birds can not wade in limnetic portions of a lake system, it is not surprising that mean depth values were not significantly related to bird abundance, and species richness. The width of the immediate shoreline that can be used by many wading birds, however, is potentially important. This width would be related to the slope of a lake system, out from the shoreline, which would determine the maximum depth at which many bird species could wade and forage for food. **The slope of a lake has also been related to patterns in aquatic macrophyte biomass and coverage (Canfield and Duarte 1988),** ***thus slope rather than shoreline development or mean depth may be the most important factor influencing bird abundance and species richness after the effects of trophic status are accounted for."*** They go on to say (p.580)... **"We also believe that near-shore terrestrial vegetation may be very important to bird populations using lakes because we observe the majority of birds near shoreline areas".**

Lake trophic status

William et al. (1985) state (p. 58): "Trophic status refers to the fertility of a lake and is a direct function of nutrient loading. Oligotrophic, nutrient-poor lakes, generally have littoral zone plant communities that provide habitat for sport and forage fish, but lack of nutrients inhibits production so that total biomass and potential harvest of fish is low. The low nutrient supply also inhibits phytoplankton production in open water areas, so that limnetic fish populations are severely limited."

Littoral zone development of rooted aquatic plant community

Williams et al (1985) point out that early in the eutrophication process there are benefits to fish populations and habitat conditions, but a point is reached where the system becomes degraded. Increasing nutrient loading eventually can lead to hypereutrophic conditions, with increased density of littoral plants (phytoplankton, and floating macrophyte, e.g. water hyacinth), decreased dissolved oxygen, increased phytoplankton turnover and development of mucky sediments, declines in sport and forage fish populations, increase in "rough fish" populations.

William et al give extensive details and reviews of habitat characteristic of lakes that are beneficial to forage fish, sport fish, and overall lake quality. They also emphasize the role of periodic "drawdowns", as have Weller (1982) and Fredrickson and Laubhan (1994) in improving overall quality of littoral zones for vegetative interspersion, habitat quality, forage fish populations, and habitat for sport fish nesting.

In discussing what they consider to be possibly the "most highly prized freshwater game fish in Florida", the largemouth bass, Williams et al state (p.62) that "Florida bass are largely oriented to the littoral zone, preferring shallow, highly vegetated areas. Blocknet samples taken from lake Kissimmee showed a littoral/limnetic population density ratio of 10:1 for harvestable sized bass (greater than 25 cm TL), while the littoral/limnetic density ratio for lake Tohopekaliga was 16:1 in 1977. Similar ratios for Lake Dora and Griffin were respectively 33:1 and 38:1 by number and 29:1 and 30:1 by weight."

Other perspectives on habitat characteristics beneficial to wetland animals

As pointed out by Weller (1982:943) in his classic paper on the management of freshwater marshes for wildlife, his two main objectives were "the preservation of marshes in a natural and esthetically pleasing state (with or without manipulation" and "to maintain high productivity of characteristic flora and fauna in marsh units."

Weller recognized the importance of the wide diversity of semi-aquatic and upland species that seasonally use and contribute to the productivity and diversity of wetland settings, especially water birds. He noted (p. 943) that "Commonly, marshes are viewed as basins that can be changed to a unit more productive of a single species or complex of species other than those found there at a given time." And he considered it important in both natural and artificial wetlands to maintain species diversity for overall health of the system.

He reviewed the literature on nesting by wetland birds and noted:

1. There was a positive correlation between the number of bird nests with the number of plant communities in marshes.

2. Many marsh birds nest near water-cover interfaces or the meeting of two cover type.

3. Most species favor marshes in a "hemimarsh" stage with a ratio of 1:1 cover-water interspersion.

4. The greatest species richness and greatest density of nests occurred where there was high interspersion of open water within the vegetated portions of marshes (ranging form 1:1 to 1:2 cover-water interspersion).

5. Marshes with a complex plant zonation also have several layers of vegetation (Fig. 44).

6. To preserve a typical marsh avifauna, it is best to have several wetland types, as well as upland areas present.

He also reviewed the importance of aquatic invertebrates and mammals in overall wetland function and concluded that **a healthy marsh is part of a wetland -**

upland complex that includes fully aquatic, semi-aquatic and upland species (e.g. herbivores such as nutria, deer, muskrat). He stated that (p. 945) "Stability seems deadly to marsh systems, at least where terrestrial or semiaquatic faunas are preferred to open marsh or lake faunas."

EVALUATION OF CURRENT DESIGNS FOR LAKES AND LITTORAL ZONES

The factors reviewed above were used to evaluate the current pattern of lakes in the study area as well as the SFLMC's proposed Lake Belt Plan. Several problem areas were identified. Each problem will be discussed, along with potential solutions to be considered in future designs.

Lake depths

Problem: The lakes are too deep (they are all greater than 30 feet (10 m) in depth (more often greater than 60 feet (20 m) in depth). Deep lakes are generally poor habitat for fishes in this region. Digging shallower lakes will have a negative overall impact, because more lakes will have to be dug to meet rock mined materials demand.

Solution: Little can be done on this variable if all future lakes must meet a single design plan. Therefore, development of two mining zones with different lake characteristics is recommended. This is discussed in further detail below.

Littoral zone width

Problem: Existing littoral zones are too narrow relative to lake surface area. Estimates of littoral area surrounding existing Florida lakes range widely, but the portion of a lake-littoral complex that is commonly littoral zone is between 10 and 30%. For a one square mile area, that is equivalent to 64 to 192 acres of littoral zone. The more area available to littoral zones, the more forage and sport fish will be available.

Solution: Littoral zones, of at least some lakes should be made wider, and approach 10 - 30% of the areal extent of the total lake littoral complex (see below).

Shoreline development

Problem: The current littoral zones have minimal shoreline development. They are a straight edge. As pointed out above, the greater the shoreline development the more productive the zone is.

Solution: The edges of at least some lakes should be designed to include greater variation in edge structure, such as coves and peninsulas.

Littoral zone depth and slope

Problem: The littoral zones lack zonation in depth and therefore vegetation. As pointed out above, littoral zones should make a gentle gradual transition form dry land to deep water. This permits seasonal changes in water depth, and seasonal changes in the percentage of area inundated.

Solution: The littoral zones should be dug to have a sloping gradient from waters edge to approximately about three feet (one meter). The degree of the slope will be determined by the width of the littoral zone. Littoral zone width would be determine by the size of the lake.

A preliminary estimate of littoral zone width is based on the following generalizations for healthy, natural systems. Firstly, a unit of marsh has about one-tenth the productivity of a unit of littoral zone (see Williams et al, 1985; Canfield and Hoyer, 1992; and information herein for some of the available estimates). Therefore, loss of a square mile (640 acres) of marsh requires a minimum of 64 acres of littoral productivity to compensate. This acreage could be distributed equally among all sides of the lake, unequally among some sides, or solely along one side of the lake. For simplicity of calculation, considered the 64 acres distributed along only one side of the lake. The littoral zone would then need to be one mile long and 1/10th mile wide (530 foot). Secondly, a natural and healthy littoral zone should have depths ranging from zero to three feet along a gentle slope. This would allow it to sustain an invertebrate and forage fish assemblage, a sport fish (large mouth bass) breeding and nursery habitat, depths suitable for wading bird and shorebird foraging habitat, and zonation of submerged and emergent macrophytes. Without depths suitable to wading bird foraging, productivity of macro-invertebrates and fishes would not be available to these consumers. Now take, for example, a square mile lake-littoral zone complex, with the littoral zone restricted to one edge of the lake. For a minimal littoral zone design of 10% of the lake-littoral area, the littoral zone would be a minimum of 1/10 th mile wide (530 feet or 175 m). To generate maximum depths of three feet, the slope of the littoral zone would be approximately one degree.

Interface to shoreward habitat

Problem : The littoral zones currently have little or no interface to upland habitat required by wetland seasonal, semi-aquatic, and upland species that normally use wetland edges. Currently, the littoral zones interface to either narrow roadway/levees or melaleuca invaded areas. The littoral zones should have some interface to upland habitat required by wetland seasonal, semi-aquatic, and upland species that normally use wetland edges. Future development of relatively narrow strips of land from what where originally haul roads, may be of use as greenways, and even as corridors for movement, but would be so limited in areal extent as to preclude maintenance of populations of many species including white-tailed deer, bobcat, gray fox. There is almost no place for semi-aquatic and upland species to reside, bask, or lay eggs.

Solution: Plan to include sufficient acreage of land adjacent to lakes that can function as marsh and seasonally dry areas. Addition of native trees in these areas would benefit many bird species and semi-arboreal herptiles (treefrogs, some snakes). These areas will be especially critical to maintaining mammalian populations in the area.

ALTERNATIVES TO CURRENT CONDITIONS

With no action there will be continuing spread of melaleuca and decrease in habitat quality. Without changes to the exiting pattern of rock mining, there will continue to be a patchwork of varying formats or configurations of lakes with narrow, single depth littoral zones that will have limited mitigation value. Therefore, the "No Action" alternative will result in a continuing loss of wildlife habitat value.

The best alternative should include compartmentalization of mining activities. Within a region, mining should occur first in areas with the highest melaleuca density. In areas where little mining should occur (Pennsuco wetlands), melaleuca should be removed in order to prevent habitat degradation.

A three subregion alternative along an east-west gradient is suggested. The degree of rock-mining would differ between the regions. More importantly, lake configurations in the different regions would be determined by different criteria (e.g. maximize recovery of rock versus promote wildlife habitat). This approach is consistent with initial configurations being considered by SFWMD for hydrological modeling.

The region east of the existing FPL R/W would be an area of intensive rock mining. Lake configuration would be designed to maximize mining potential. Therefore, lakes would be dug to maximum depths, with minimal littoral zone designs, and, or on-site mitigations. Zone wide water management would be least harmful to habitat heterogeneity in this eastern "intense" management area. In the future, portions of this zone could be modified and opened to intense public recreational activities (such as sail and power boating activities) as agencies are inclined. The haul roads could be developed as a greenway that could serve public recreational needs (e.g. biking, hiking), and also serve as minimal wildlife corridors connecting to the western two thirds of the region.

The region between the existing FPL right of way and the Dade-Broward Levee would be a transition zone. Lake configuration would be designed to promote wildlife habitat. This would include shallower lake depths and maximum littoral zone development in terms of area, width, slope, and zonation. Areas with the greater than 75% melaleuca coverage should be preferentially mined. Mining should be minimized in areas with low to moderate melaleuca coverages. The results of this study have demonstrated that they retain a full complement of native wetland species. Therefore, they would serve as a nearby-source of animals to populate the littoral zones. Provisions should also be made for maintaining or enhancing east-west corridors. The Dade-Broward levee or an equivalent area would serve as a north-south wildlife corridor, and would be of use by semi-aquatic species from both the Pennsuco Everglades and the central zone. Variations in water levels due to human management, could be localized on a year to year basis to increase variation in drawdown and or flooding, and therefore promote lake to lake heterogeneity (which is beneficial to lake system management for wildlife, see above).

The western region would be west of the Dade-Broward Levee (the Pennsuco Everglades). It would be maintained as a functional marsh with appropriate seasonal and annual variations in depth and duration of flooding. This region will act as a significant area of wetland for use by resident species, and as peripheral wetlands for wide ranging users, such as wading birds.

Since management goals are likely to change through time, the design should allow for flexibility in management approaches. The suggested plan would make it possible to implement a variety of management techniques. The following list of suggested management practices and, or principals should be considered (see Weller, 1982: 949-954):

1. System management, rather than species by species management, results in widespread benefits to all wildlife and plants.

2. Management to produce early plant successional stages results in longer lasting benefits, and creates diverse habitat niches.

3. For improved habitat heterogeneity in wetland complexes, all units in an area should not be managed in the same manner at the same time.

4. Wetland:upland ratios that preserve natural patterns and diversity should be used.

5. Natural or artificial simulation of drawdown, especially within subregions of the system will benefit productivity in marshes, littoral and limnetic zones (also see Kadlec, 1962; Meeks, 1969; Williams et al, 1985; and Fredrickson and Laubhan, 1994).

In addition, artificial habitat enhancements could be included. Numerous authors have discussed and recommended a variety of techniques to improve habitat value. Artificial **fish attractors** to improve sport fishing by anglers are currently popular in many Florida lakes and are managed by the Florida Game and Fresh water Fish Commission. But Williams et al (1985:102) emphasize that **"Their primary purpose is to concentrate existing fish populations to provide increased angler success and sportfish harvest, rather than increasing the biological productivity of a lake system."**

A number of additional actions that can be considered for wildlife habitat improvement include **native tree islands and littoral edge stands of willow, cypress, or pond apple** to improve ecotones between open water shoreline and marsh habitat. **Isolated island systems in lakes** with native macrophytes and trees to promote water and wading bird roosting, and breeding habitat that is isolated from human disturbance and mammalian predators (also see Hammond and Mann, 1956; Sargeant, 1982). **Points of land, isthmuses, or splts** of land along shorelines will be beneficial to overall productivity, habitat diversity, and maintenance of upland-wetland species requirements (cf. e.g. Newman and Griffin, 1994).

Once the regional implications of the various options for this region are interpreted in terms of private and public needs, many of the above suggestions could be integrated into the final configuration of the lake and littoral complex. The options listed above are only a preliminary list. They are readily attainable and should be recognized as opportunities to "fine tune" the ultimate lake and littoral designs. Hopefully, after the hydrological, economic, and social issues have been integrated into the analyses, the final plan developed for the Lake Belt Study Area will recognize and recommend that the existing biological resources of the area can be preserved and even enhanced.

LITERATURE CITED

Allen, C. R., R. S. Lutz, and S. Demarais. 1993. What about fire ants and northern Bobwhites. Wildlife Society Bulletin 21:349-351.

Bancroft, G.T., S.D. Jewell, A.M. Strong. 1990. Foraging and Nesting Ecology of Herons in the Lower Everglades Relative to Water. Final report to the South Florida Water Management District, West Palm Beach, Florida. 167 pp.

Bishop, S.C. 1962. Handbook of Salamanders. The Salamanders of the United States, of Canada, and of Lower California. Hafner Publishing Company, New York.

Campbell, H.W. and Christman, S.P. 1982. The herpetological components of Florida sandhill and sand pine scrub associations. Pages 163-171 *in* Norman J. Scott, editor U.S. Fish and Wildlife Service Wildlife Research Report 13. Washington, D.C.

Canfield, D.E., Jr. and C.M. Duarte. 1988. Patterns in biomass and cover of aquatic macrophytes in lakes: a test with Florida lakes. Can. J. Fish. Aquat. Sci. 45:1976-1982.

Canfield, D.E., Jr. and M.V. Hoyer. 1992. Aquatic Macrophytes and Their Relation to the Limnology of Florida Lakes. Final Report. Florida Dept. of Fisheries and Agriculture. Center for Aquatic Plants. Univ. of Florida. Gainesville. 598 + liii pp.

Cody, M.L. 1985. Habitat selection in grassland and open-country birds. Pages 191 - 226, *in* M.L. Cody, Habitat Selection in Birds. Academic Press.

Dalrymple, G. H. 1988. The herpetofauna of Long Pine Key, Everglades National Park, in relation to vegetation and hydrology. Pages 72 - 86, *in* R. Szaro, K.E. Severson, and D.R. Patton, (technical coordinators), Management of Amphibians, Reptiles, and Small Mammals in North America. U.S.D.A. Forest Service. General Technical Report RM-166. Fort Collins.

Dalrymple, G. H. 1994. In-faunal Study of Wetland Restoration in the Hole-in-the-donut, Everglades National Park 1990-1992. Final report to South Florida Research Center, Everglades National Park.

Dalrymple, G.H. 1995. Baseline Studies of Addition Lands of the Big Cypress National Preserve. Submitted to Big Cypress National Preserve, October 16, 1995. 40 pp.

Dalrymple, G.H. and O.L. Bass, Jr. In press. Diet of the Florida Panther in Everglades National Park. Bulletin of the Florida State Museum.

Davis, J.H. Jr. 1943. The Natural Features of Southern Florida, Especially the Vegetation, and the Everglades. Florida Geological Survey. Tallahassee.

Davis, S.M., L.H. Gunderson, W.A. Park, J.R. Richardson, J.E. Mattson. 1994. Landscape dimension, composition, and function in a changing Everglades ecosystem, pages 419-444 *in* S.M. Davis and J.C. Ogden, eds. Everglades. The Ecosystem and its Restoration. St. Lucie Press. Delray Beach, FL.

Dickinson, R.E., P.L. Brezonik, W.C. Huber, and J.P. Heaney. 1982. Gazetteer of Florida Lakes. Florida Water Resources Research Center Pub. No. 63. Florida Department of Environmental Regulation, Tallahassee, Florida.

Duellman, W. E., and A. Schwartz. 1958. Amphibians and reptiles of southern Florida. Bull. Florida State Museum 3:181-324.

EAS Engineering, Inc. 1995. Year One Report on Vegetation of the Lake Belt Study Area. Report submitted to Dade County, Department of Environmental Resources Management, April 1995.

Ehrlich, P.R., D.S. Dobkin, D. Wheye. 1988. The Birder's Handbook. A Field Guide to the Natural History of North American Birds. Simon & Schuster, Inc.

Fennema,, R.J., C.J. Neidrauer, R.A. Johnson, T.K. MacVicar, and W.A. Perkins. 1994. A computer model to simulate natural Everglades hydrology. Pages 249-289 *in* S.M. Davis and J.C. Ogden, eds. Everglades. The Ecosystem and its Restoration. St. Lucie Press. Delray Beach, FL.

Frederick, P.C. and M.W. Collopy. 1988. Reproductive Ecology of Wading Birds in Relation to Water Conditions in the Florida Everglades. Florida Coop. Fish and Wildl. Res. Unit. Sch. For. Res. and Conserv., Univ. of Florida. Tech Rept. No. 30.

Fredrickson, L.H. and M.K. Laubhan. 1994. Managing wetlands for wildlife. Pages 623-647 *in* T.A. Bookhout, ed. Research and management techniques for wildlife and habitats. Fifth ed. The Wildlife Society, Bethesda, MD.

Fredrickson, L. H., and F. A. Reid. 1986. Wetland and riparian habitats: a non-game management overview. Pages 59 - 96, *in* LF. B. Hale, L. B. Best, and R. L. Clawson, eds. Management of Nongame Wildlife in the Midwest: a Developing Art. North-Central Section, The Wildlife Society, Grand Rapids, Michigan.

Hammond, M.C., and G.E. Mann. 1956. Waterfowl nesting islands. J. Wildl. Manage. 20:345-352.

Heyer, W.R., M.A. Donnelly, R.W. McDiarmid, L.C. Hayek, and M.S. Foster. 1994. Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington and London.

Hurlbert, S.H. 1984. Pseudoreplication and the design of ecological experiments. Ecological Monographs 54(2): 187-211.

Kadlec, J.A. 1962. Effects of a drawdown on a waterfowl impoundment. Ecology 43:267-281.

Keller, C. M. E., C. S. Robbins, and J. S. Hatfield. 1993. Avian communities in riparian forests of different widths in Maryland and Delaware. Wetlands 13:137-144.

Krebs, C. J. 1989. Ecological Methodology. Harper and Row, Publ. New York. 654 + xii p.

Kushlan, J. A. 1974. Quantitative sampling of fish populations in shallow. freshwater environments. Trans. American Fisheries Society 103:348-352.

Larsen, P. W. 1992. South Florida Limestone Mining Coalition Year 2050 Fresh Water Lake Belt Plan. Larsen and Associates, Miami, Florida.

Layne, J. N. 1984. The land mammals of South Florida. Pages 269-296 *in* P.J. Gleason (ed.) Environments of South Florida Present and Past II. Miami Geological Society. Miami.

Lewis, E.A. 1994. Resource Use by the Woodpeckers of Long Pine Key, Everglades National Park. Unpublished Master's thesis, Florida International University. 70 pp.

Loftus, W.F., and A. Eklund. 1994. Long-term dynamics of an Everglades small-fish assemblage. Pages 461-483 *in* S.M. Davis and J.C. Ogden, eds. Everglades. The Ecosystem and its Restoration, . St. Lucie Press Delray Beach, FL.

Loftus, W. F. and J. A. Kushlan. 1987. Freshwater fishes of southern Florida. Bulletin of the Florida State Museum, Biological Sciences. 31:147-344.

Loughlin, M.H., J.C. Ogden, W.B. Robertson, Jr., K. Russell, and R.W. March. 1990. Everglades National Park Bird Check List. Florida National Parks and Monuments Association, Inc. Homestead, Florida. 18 pp.

Mazzotti, F. J. Ostrenko, W. and A. T. Smith. 1981. Effects of the exotic plants Melaleuca quinquenervia and Casuarina equisetifolia on small mammal populations in the eastern Florida Everglades. Florida Scientist 44:65-71

McIvor, C.C., and W.E. Odum. 1986. The flume net: a quantitative method for sampling fishes and macrocrustaceans on tidal marsh surfaces. Estuaries 9(3): 219-224.

McIvor, C.C., and W.E. Odum. 1988. Food, predation risk, and microhabitat selection in a marsh fish assemblage. Ecology 69(5): 1341-1351.

Meeks, R.L. 1969. The effect of drawdown date on wetland plant succession. J. Wild. Manage. 33:817-821.

Mitsch, W.J. and J.G. Gosselink. 1986. Wetlands. Van Nostrand Reinhold, New York.

Moler, P.E (editor). 1992. Rare and Endangered Biota of Florida. University Press of Florida.

Morse, D.H. 1985. Habitat selection in North American parulid warblers. Pages 131 - 157, *in* M.L. Cody, Habitat Selection in Birds. Academic Press.

Moyer, E.J. and V.P. Williams. 1982. Macroinvertebrate production in box-cut access channels versus natural vegetated lake bottom. Proc. Ann. Conf. S.E. Assoc. Game Fish Comm. 11:89-91.

Newman, D.G., and C.R. Griffin. 1994. Wetland use by river otters in Massachusetts. J. Wildl. Manage. 58:18-23.

Odum, E.P. 1983. Basic Ecology. Saunders College Publishing.

Peterson, R.T. 1980. A Field Guide to the Birds, Eastern Birds. 4th edition. Houghton Mifflin Company, Boston.

Repenning, R. W. 1986. Mitigation of Fish and Wildlife Values in Rock-mined Areas of South Florida, Part Ii: Wildlife. Cooperative Fish and Wildlife Research Unit Report. University of Florida. 1986.

Robertson, W. B. Jr. 1955. An Analysis of the Breeding-bird Populations of Tropical Florida in Relation to the Vegetation. Ph.D. Dissertation, University of Illinois, Urbana.

Robertson, W. B. Jr., and J. A. Kushlan. 1984. The southern Florida avifauna. Pages 219-257 *in* P.J. Gleason (ed.) Environments of South Florida Present and Past II. Miami Geological Society. Miami.

Runde, D.E., J.A. Gore, J.A. Hovis, M.S. Robson, and P.E. Southall. 1991. Florida Atlas of Breeding Sites for Herons and their Allies Update 1986-1989. Florida Game and Fresh Water Fish Commission. Nongame Wildlife Program Technical Report No. 10.

Sargeant, A.B. 1982. Red fox spatial characteristics in relation to waterfowl predation. Pages 98-109 *in* J.T. Ratti, I.D. Flake, and W.A. Wentz, eds. Waterfowl Ecology and Management: Selected Readings. The Wildlife Society, Inc. Bethesda, Md. (originally published in 1972).

Schortemeyer, J.L., R.E. Johnson, and J.D. West. 1981. A preliminary report on wildlife occurrence in melaleuca heads in the Everglades Wildlife Management Area. Pages 81 - 89 *in* Geiger, R.K. (ed.). Proceedings of Melaleuca Symposium, held September 23-24, 1980, Edison Community College, Ft. Myers, Florida. Florida Dept. of Agriculture and Consumer Services. Division of Forestry, Tallahassee.

Smith A. T., ad J. M. Vrieze. 1979. Population structure of Everglades rodents: responses to a patchy environment. Journal of Mammalogy 60:778-794.

Sokal R. R., and F. J. Rohlf. 1981. Biometery. W. H. Freeman and Co. New York. 859 + xviii.

Sowder, A. and S. Woodall. 1985. Small mammals of Melaleuca stands and adjacent environments in southwestern Florida. Florida Scientist 48:44-46.

Stauffer, D. F. and. B. Best. 1980. Habitat selection by birds of riparian communities: evaluating effects of habitat alterations. Journal of Wildlife Management: 44:1-15.

Wegener, W., D. Holcomb and V. Williams. 1973. Sampling shallow water fish populations using the Wegener ring. Proc. Ann. Conf. S.E. Assoc. Game Fish Comm. 27:663-674.

Weller, M. W. 1982. Management of freshwater marshes for wildlife. Pages 942-956 *in* J.T. Ratti, I.D. Flake, and W.A. Wentz, eds. Waterfowl Ecology and Management: Selected Readings. The Wildlife Society, Inc. Bethesda, Md. (originally published in 1978).

Williams, V.P., D.E. Canfield, Jr., M.M. Hale, W.E. Johnson, R.S. Kautz, J,T, Krummrich, F.H. Langford, K. Langland, S.P. McKinney, D.M. Powell, and P.L. Shafland. 1985. Lake habitat and fishery resources of Florida. Pages 43-119 *in* W. Seaman, Jr., ed. Florida Aquatic Habitat and Fishery Resources. Florida Chapter of American Fisheries Society. Kissimmee, FL.

Wilson, L.D., and Porras. 1983. The Ecological Impact of Man on the South Florida Herpetofauna. University of Kansas, Lawrence.

Wood, D.A. 1994. Official lists of endangered and potentially endangered fauna and flora in Florida. Florida Game and Fresh Water Fish Commission, Tallahassee. 22 + ii.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. J. Wild. Manage. 47:893-901.